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Municipal/Industrial Strategy for Abatement

BACKGROUND DOCUMENT ON THE DEVELOPMENT OF THE DRAFT PETROLEUM REFINING SECTOR EFFLUENT LIMITS REGULATION

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2.0 - THE INDUSTRIAL SECTOR

2.1 - INDUSTRY PROFILE

The petroleum refining sector is relatively homogeneous. Refinery processing primarily rearranges the structure of hydrocarbon molecules. It does not generally involve the addition of other substances to feedstocks to create entirely dissimilar derivatives. It is therefore logical to assume that studies conducted at selected refineries might, under certain circumstances, be applicable to other similar operations.

Raw Materials

The principal feedstock is crude oil. Crude oil is a mixture of thousands of different compounds and varies in composition and physical properties, depending upon its source. There are two principal types of crude oil, natural (as found in underground formations) and synthetic (as produced by extraction and processing of tar sands). In addition to the hydrocarbon component, crude oil may contain varying amounts of sulphur and trace amounts of compounds containing nitrogen, oxygen, and heavy metals such as iron, nickel, chromium, and vanadium.

Products

The basic function of a refinery is to process crude oils into a variety of petroleum products required by an industrialized society. Moreover, it is important to note that a typical refinery produces petrochemical feedstocks that are the raw material for many products manufactured by other industries.

While not all refineries necessarily make a full range of products, generally speaking, refineries transform crude oil into about 700 products including greases, waxes, asphalts, lubricating oils, several grades of gasoline, many grades and types of fuel oils (i.e. diesel, home heating, industrial and heavy fuel oils), and petrochemicals.

The primary petrochemical refinery can utilize a wide range of feedstocks in addition to crude oil, including natural gas liquids (ethane, propane, and butane), and vacuum gas oil. The choice depends upon the product requirements and the price and availability of the raw materials. The primary petrochemicals produced are ethylene, propylene, butadiene, butylenes, benzene, toluene, and xylene.

Refinery Processes

The first process step in a refinery consists of physically separating crude oil into a number of fractions of varying molecular weights by distillation. Subsequent conversion processes are then required for intermediate and final products. Although more than 150 separate processes have been identified in the industry, they can generally be classified as either physical separation or chemical conversion operations.

Distillation, liquid extraction and crystallization are examples of common physical separation processes. Cracking, reforming and alkylation are examples of the major chemical conversion processes used. Finished products are manufactured by blending various intermediate products in the required proportions. Additives, such as anti-oxidants, anti-icing agents, corrosion inhibitors, and anti-knocking agents, are added at the blending stage.

Heat removal by cooling processes is an integral part in crude oil processing.

Wastewater Sources

A refinery generates contaminated water in a number of ways:

- crude oil itself contains a small amount of water;
- steam is added in the processing operations to aid in the distillation or to 'strip' out impurities;
- ballast water from tank ships transporting petroleum products is pumped ashore when products are loaded;
- water accumulates in the bottom of storage tanks and must be drawn off from time to time;
- periodic discharge, or blowdown, of recirculating cooling water systems;
- storm water runoff from process areas and tank farms.

Contaminants in Refinery Effluents and Present Legislation

Phenolics, sulphides, ammonia, suspended solids and oil and grease are typical pollutants generated by the refineries. The major conventional pollutants that are federally regulated in Canada and in the United States are the parameters described below.

In Ontario, the petroleum refineries control five parameters which are considered representative of their effluents; these parameters are:

- phenolics ("Reactive Phenols" measured by the 4-amino-antipyrine (4AAP) method);
- ammonia-nitrogen;
- total suspended solids;
- oil and grease;
- sulphide

The parameters described above along with pH are designated as 'deleterious substances' in wastewater from the petroleum refining industry under the federal Fisheries Act. The general prohibition under the act forbids the deposition of 'deleterious substances' in 'water frequented by fish'.

Section 33 of the Act empowers the Federal Environment Minister to impose regulations or guidelines designating effluent components as deleterious substances which may then only be discharged at authorized levels. Under the federal legislation, refineries are also required to measure acute toxicity to fish by a 24 hour static test.

Guidelines for older refineries, and regulations for new refineries[1] were brought into force in 1973. Under the Canada-Ontario Accord[2], Ontario applies these regulations and guidelines.

Wastewater Treatment

The aim of the Federal Regulations and Guidelines for the petroleum refining industry was to ensure that all refineries operating in Canada would apply best practicable technology (BPT) treatment to their liquid effluents.

For the purpose of the Regulations and Guidelines, this means a system equivalent to the following:

- Primary separation (such as an American Petroleum Institute (API) separator described below:

    > Oil removal from wastewater is achieved by gravity separation. The most commonly found separators are specially designed long, rectangular basins (API separators). Other more recent designs incorporate tilted plates to increase the surface area for the oil to coalesce more rapidly (eg. corrugated plate interceptors or tilted plate interceptors). The oil which rises to the surface is removed by skimming devices and returned to the refinery for reprocessing.

- Intermediate treatment (such as the air flotation described below):

    > Any traces of oil in the effluent from the separator can be further decreased with such processes as dissolved air flotation, induced air flotation, and filtration with sand or mixed media, as required.

- Secondary treatment (the biological oxidation described below):

    > Wastewater from all of the primary containment and treatment steps is collected in a feed equalization pond to smooth out the quality and quantity of the feed to the "secondary" treatment stage, the biological oxidation unit. These ponds typically provide anywhere from 12 hours to several days retention time.
    >
    > The wastewater is fed into an aerated basin which contains bacteria, which have been conditioned to consume the organic contaminants remaining in the wastewater. The biological activity produces new cell matter (to propagate the species), carbon dioxide, and water.

A final clarification and the effluent polishing step removes any biological floc or other suspended matter. It also adds further hold-up and equalization in the system before the treated wastewater is discharged to the receiving water.

- Sour water stripping for ammonia and sulphide removal:

  Some of the wastewater streams contain appreciable quantities of ammonia and sulphides. These are removed in a steam stripping column, called a sour water stripper, prior to further treatment using the system as outlined above.

- Good housekeeping, such as sewer segregation:

  The sewer systems in which on-site wastewater is collected and transferred to the wastewater treatment plant are designed to keep the various types and strengths of wastewaters separate in order to facilitate more efficient and effective treatment. An example of this is the segregation of sour waters.

- Storm water falling on the developed areas of a refinery site is collected in large retention ponds. The ponds are subsequently tested and either discharged or treated, depending upon the quality.

All wastewater treatment systems in the petroleum refineries operate with a Certificate of Approval obtained from the Ministry under the Ontario Water Resources Act prior to the construction of the treatment system.

2.2 - PETROLEUM REFINING SECTOR IN ONTARIO

The petroleum refining sector in Ontario consists of seven plants. Only three of the seven plants (Suncor, Petro-Canada - Oakville, and Esso - Nanticoke) can be considered as conventional refineries in the strictest sense (as defined in the Federal Regulation). Nova Petrochemicals produces feedstocks for the nearby petrochemical industries and markets a very limited number of conventional petroleum products. Petro-Canada - Mississauga Refinery processes sufficient crude oil to produce lubricating oils and greases to meet the market demand. Shell Canada and Esso Petroleum in Sarnia produce an extensive list of petrochemicals going well beyond the production of benzene, toluene and xylene. The latter are normally considered as conventional refinery products according to the definition of a refinery as established by Environment Canada in Petroleum Refinery Effluent Regulations and Guidelines in 1974. Both Shell Canada and Esso Petroleum in Sarnia employ integrated wastewater treatment plants for refinery and petrochemical production.

2.2.1 Status of Wastewater Generation in Ontario Refineries

Information about each refinery including age and location, production capacities, processes used, wastewater sources, and the composition and treatment of refinery effluents is covered in Part II of the consultant's report on Best Available Technology For The Ontario Petroleum Refining Sector, April 1992[3].

The consultant's report summarizes the status of the seven refineries in 1989 during the in-depth sampling and testing program (MISA monitoring) carried out in that year. Included in the report is a review of existing pollution control requirements with which the refineries must comply, along with a comparison of the MISA Effluent monitoring data with effluent limitations, standards, and guidelines from other jurisdictions.

Cooling methods vary considerably from plant to plant. On the one hand, Nova Petrochemicals is almost completely cooled by recirculated cooling water while Esso Nanticoke is 85% air cooled. Between these extremes, the remaining five plants employ mixtures of once through cooling water, air cooling and recirculated cooling water. Recent trends are towards maximum use of air cooling when new equipment is installed. Phosphate based additives have replaced zinc-chromium additives for recirculated water systems at all four plants which have used them during the year of monitoring.

A number of methods for recycling and reusing water within the plants are already in use. The use of stripped sour water for desalter make up, the recycling of steam condensate, the recycling of pump and compressor gland water, and the minimization of cooling tower blow down are all employed. The consultant's report identifies selected sources of wastewater in each plant and recommends approaches for reduction. The report states that the actual reductions of waste water can only be established after thorough in plant studies have been done.

The ratio of process wastewater to feedstock varies from plant to plant.

The seven plants all use modern wastewater treatment methods. Storm water is segregated in all cases but not always in the same way. Ballast water in all cases receives full biological treatment. The process wastewater is treated along conventional lines: API separators, air flotation or dual media filters followed by equalization basins, biological treatment, and clarification before discharge. Final dual media filtration of the effluent, plus ponding, is practised in one plant while another refinery uses granular activated carbon mainly for periods when the storm water system is overloaded. On occasion, the filters are used to treat process effluent.

Compliance with Ontario's Effluent Quality Objectives for the refineries was good in 1989. Suspended solids were the major source of non-compliance in some refineries.

A review of management practices in the Ontario refineries shows that the wastewater treatment units are considered as important as the process units. Operating specifications and control tests for the wastewater treatment units are used at all refineries. Responsibility and authority within the wastewater treatment plant has been clearly defined. Operators attend a one week course of instructions at local colleges using a manual developed by the Petroleum Association for Conservation of the Canadian Environment (PACE) and the Ontario Petroleum Association which is now the Canadian Petroleum Products Institute (CPPI). Environmental personnel are routinely involved at the very earliest stages of new project development.

The 1989 spills report[3] stated that thirty-eight liquid spills were reported by the seven refineries to the Ministry. Regardless of size every spill must be reported. The larger spills occurred inside the refineries but there were also some small spills around the docks. In all cases, these spills were cleaned up. Some plants have initiated programs to reduce the frequency and severity of spills through training, increased vigilance and risk analysis.

2.2.2 Description of Petroleum Refineries in Ontario

Esso Petroleum - Nanticoke Refinery

The Esso Petroleum Nanticoke refinery, which was originally owned by Texaco, is the newest refinery in Ontario. The refinery was completed in 1978 with a crude oil processing capacity of approximately 19,000 cubic meters per day. It is located south-west of Hamilton on the north shore of Lake Erie. The refinery utilizes atmospheric and vacuum distillation, fluid catalytic cracking, catalytic reforming, hydrogen treating, alkylation, and sulphur recovery processes. Finished products include leaded and unleaded gasolines, jet fuels, heating oils, diesel, industrial fuels, liquified propane and butane, and sulphur.

Approximately 85% of the refinery's cooling requirements are fulfilled by air rather than water. Water usage is minimized by recirculating the water through a cooling tower and by re-use of process waters and steam condensate.

Pre-treatment at the source, by sour water stripping or spent caustic neutralization, is provided for certain wastes. Other waste streams that are segregated include: process wastewaters, ballast water, clean storm water, sanitary wastes, cooling tower blowdown, and other streams containing high dissolved solids and oil wastes. All waste streams are directed to the wastewater treatment plant for final processing before discharging to Lake Erie.

Wastewater is treated sequentially through API separators, feed equalization, dissolved air flotation, biological activated sludge, secondary clarifiers, polishing filters, and final effluent containment ponds. The wastewater treatment plant also has a containment pond to allow the recycle of waste streams being treated.

Uncontaminated storm water has a segregated sewer/ditch system leading to a modified API separator before being collected in two clean storm containment ponds. The effluents from these ponds are analyzed prior to discharge and can be routed to the wastewater treatment plant if necessary.

Esso Petroleum - Sarnia Refinery

The Esso Petroleum refinery in Sarnia is almost 100 years old. It has a crude oil capacity of 20,000 cubic meters per day and it produces various fuel products, lubricating oils and greases, and petrochemical products. Major processes include: atmospheric and vacuum distillation, catalytic cracking, fluid coking, hydrocracking, catalytic reforming, alkylation, polymerization, hydrogen treating, hydrogen production, lube oil processing and packaging, and sulphur recovery production.

The refinery has segregated systems for treating once-through cooling water and oil contact water.

Once-through cooling water is treated in four parallel API separators for solids and oil removal prior to discharge.

Oil contact water consists of process wastewater, storm water, ship ballast water, tank water draw-off, and landfarm leachate. The wastewater treatment sequence is comprised of API oil/water separation, sand/anthracite filtration, biological oxidation, and clarification.

Sour water is steam stripped to remove sulphides and ammonia and then transferred to a separate biological oxidation unit. The effluent is then combined with the filtered oil contact water and transferred to another biological oxidation unit which is part of the effluent treatment plant.

Storm water storage is provided in tanks, which are designed to contain the runoff from a one in 10 year storm event, in order to prevent the overloading of the treatment facilities.

An active source control program quickly identifies and corrects leaks or other problems before they can adversely affect the operation of the treatment plant.

Novacor - Corunna

Novacor's petrochemical refinery complex commenced operation in 1978 as Petrosar Limited. It processes up to 15,000 cubic metres per day of crude oil, condensate, and natural gas liquids for the production of 1.3 million tonnes per year of primary petrochemicals (ethylene, propylene, butadiene, iso-butylene, n-butylene, benzene, and toluene/xylene).

Naphtha, heavy atmospheric gas oil, vacuum gas oil, No. 2 fuel oil, ethane, propane, and butane are all produced as intermediate or final products. Whether they are further processed (i.e. cracked) or sold depends upon market demand and economics.

The main production processes in the complex are atmospheric and vacuum distillation, olefin cracking and separation, gasoline hydrotreating, and aromatics extraction.

The wastewater from these processes is segregated into four types: chemical or process wastewater, oily water, storm water, and sanitary wastewater.

All chemically or oily contaminated water is treated in a secondary treatment plant consisting of oil/water separation, retention pond, biological oxidation, and clarification. Storm water is treated to remove suspended solids and traces of oil (occasionally through activated carbon filters). Sanitary wastewater is treated in a separate biological unit.

Petro-Canada Lake Ontario Refinery - Mississauga Plant

Petro-Canada's Mississauga Plant (previously Gulf Oil) was opened in 1943 by the British American Oil Company. The facility encompasses a refinery and lubricants plant including a compounding, blending, and grease plant. In response to a decline in market demand, the refining portion of the facilities was downsized in 1984. It can now process up to 7,300 cubic meters per day of Canadian crude oil into a variety of products, including liquid petroleum gases, aviation fuel, motor gasolines, distillates, residual fuel oils, asphalt, lubricating oils and greases, and solvents.

This plant has a modern wastewater effluent treatment plant. The effluent treatment plant consists of a sour water stripper, an API oil separator, sand filter, equalization basin, and biological oxidation unit. It treats both process effluents and storm water. As in most older, large refineries, significant quantities of water are used for cooling in the process units. Once-through cooling water is sent to an API oil separator prior to discharge into Lake Ontario.

Petro-Canada Lake Ontario Refinery - Oakville Plant

Petro-Canada Lake Ontario Refinery - Oakville plant (previously BP-Canada) was commissioned in the Fall of 1958. The past 30 years have seen a greater than fourfold increase in the refinery's capacity. At present, the refinery can process a maximum of 13,600 cubic metres of crude oil per day. The plant produces virtually the entire range of petroleum fuel products - liquid petroleum gases, aviation gasoline, motor gasolines, distillates, residual fuel oils, asphalt and sulphur.

The wastewater effluent treatment system consists of sour water strippers, an API oil separator, equalization basin, induced air flotation and biological oxidation units. An odour control system has been installed for the induced air flotation and biological oxidation units.

Storm water is sent to an API oil separator and, depending upon the concentration of contaminants, can be treated along with the process wastewater. This refinery uses a combination of air cooling and a recirculating cooling water tower system. The combined effluent consists of process wastewater, storm water, and cooling tower blowdown, and is discharged to Lake Ontario via the surge lagoon.

Shell Canada - Sarnia Refinery

Shell's Sarnia Manufacturing Centre (SMC) is located on the St. Clair River south of Sarnia, at Corunna, Ontario. It comprises an oil refinery built in 1952 and a chemical plant built in 1979.

The Refinery has a crude capacity of 11,800 cubic meters per day. In addition to gasoline, diesel, furnace fuel and bunker fuel, the product slate includes chemicals (benzene, toluene, xylene, and sulphur) as well as hydrocarbon solvents.

The chemical plant is made up of two facilities, one for manufacturing polypropylene, the other for manufacturing isopropyl alcohol. The capacity of the isopropyl alcohol plant is 91,000 tonnes per year and the capacity of the polypropylene plant is 80,000 tonnes per year. All of the wastewater is treated in the wastewater treatment facility.

SMC takes about 200,000 to 300,000 cubic metres of water from the St. Clair River each day. The largest portion (100,000 to 200,000 cubic metres) of this water is once-through cooling water. It is used in coolers where the water pressure is higher than the product pressure, and so it is not normally contaminated. The remainder is either contaminated, or potentially contaminated, and treatment is provided.

Treatment is also provided for storm water collected in a system of in-plant ditches. In April 1988, a new 30,000 cubic metre storm water retention pond was commissioned to further enhance the capability to collect and treat storm water.

Ballast water from ships is pumped ashore and treated in the on-site wastewater treatment facility.

The wastewater treatment facility consists of API oil/water separators, dissolved air flotation, sour water stripping, flow equalization, biological oxidation, and clarification. In 1990, a third clarifier was added to improve suspended solids removal. Activated carbon filters are used for the treatment of the segregated reformer's scrubber effluent.

Suncor - Sarnia Refinery

The Suncor Sarnia refinery was built in 1953. The refinery is located on the St. Clair River immediately adjacent to, and downstream from, the major Sarnia petrochemical complexes.

The refinery processes up to 12,000 cubic meters per day of crude oil that is processed into motor gasolines, light and heavy fuels, light aromatic products, liquified gases and solid sulphur.

The refinery processes include atmospheric and vacuum distillation, catalytic cracking, hydrocracking, catalytic reforming, and BTX (benzene, toluene, xylene) aromatic extraction, as well as various strippers, hydrotreaters and scrubbers.

All gas streams containing hydrogen sulphide (H_2S) are collected and approximately 24 tonnes per day of elemental sulphur are recovered in a Claus sulphur unit.

All wastewater from condensates, contaminated storm collection systems and ballast water is treated for removal and recovery of oil. The wastewater is biologically treated before discharging to the St. Clair River through a single discharge point. Approximately 10,000 cubic metres of effluent are discharged daily together with 100,000 cubic metres of once-through cooling water. Activated carbon filters are used for the treatment of the segregated reformer's scrubber effluent.

2.3 - REFERENCES

1. Fisheries and Oceans Canada (1970). Fisheries Act. R.S.C. 1970, C.F. - 14.

2. Canada-Ontario Accord for the Protection and Enhancement of Environmental Quality. Signatories: Jeanne Sauve, Minister of the Environment for Canada, and George Kerr, Minister of the Environment for Ontario. October 20, 1975.

3. Science Applications International Corporation. Best Available Technology for the Ontario Petroleum Refining Sector. Ontario Ministry of the Environment. July 1992.

PREFACE

In 1986, the Ontario Ministry of the Environment (MOE) announced the MISA program, (Municipal-Industrial Strategy for Abatement), which was established for the purpose of reducing the discharge of toxic contaminants into Ontario's waterways. The ultimate goal of the MISA program is the virtual elimination of persistent toxic contaminants from all discharges into Ontario's waterways.

Under the first phase of MISA, dischargers were required to monitor and report on the contaminants present in their effluent streams. In the second phase, effluent compliance limits are developed through a consultative process involving the MOE, Environment Canada and industry. This process requires that limits be developed on the basis of Best Available Technology (Economically Achievable) (BAT(EA)) using the information gathered during the monitoring phase. To ensure a consistency in approach, the "Issues Resolution Committee Report", June 1990 (IRC Report) and the "Issues Resolution Process Final Report Summary, September 1991" (IRC Summary Report) were referenced.

This document describes the steps involved in the development of limits and contains the background technical information used. The document is comprised of six chapters.

The first chapter of this document is introductory and presents the environmental background to MISA and the main features of the program. A description of the Effluent Monitoring Regulation for the petroleum refining sector and the generic effluent limits regulation development process is explained.

Chapter two presents information about the petroleum refining sector. This chapter is complemented by the consultant's report on Best Available Technology for the Ontario petroleum refining sector - Part II: Status of Wastewater Generation and Treatment in Ontario's Petroleum Refineries. Included in the report is a review of existing pollution control requirements with which the refineries must comply, along with a comparison of the actual performance with effluent limitations, standards and guidelines presently used in Ontario.

The third chapter contains information about petroleum refining wastewater quality and quantity data used in the development of the effluent limits. The chapter contains a summary of the data collected as part of the Effluent Monitoring Regulation for the petroleum refining sector; the complete Effluent Monitoring Regulations database is contained in Appendices A,B,C,D, and E of this document. Information about data from sources other than the Effluent Monitoring Regulation database such as pre-regulation monitoring, is also provided.

Chapter four deals with the assessment of available pollution control technologies for petroleum refinery wastewater and identifies those technologies considered to be the "best available". This chapter is supported by the consultant's report on the Best Available Treatment Technology for the Petroleum Refining Sector - Part I.

Chapter five describes the numerical limits development process. The basis for setting limits and the method for calculating them is explained.

Chapter six presents a summary of the key components of the Effluent Limits Regulation for the petroleum refining sector. Compliance requirements and monitoring frequencies are defined as well as other regulatory requirements such as toxicity testing and flow measurement.

The regulation and the background document are the result of a joint effort on the part of the Ministry, Environment Canada, MISA Advisory Committee (MAC), industry and the public. The public was involved in the regulation development process through the review of the IRC report.

The draft version of the regulation is being released for a sixty day public review. The public review process is a key component in the development of the MISA Effluent Limits Regulations.

EXECUTIVE SUMMARY

This document describes the steps involved in the development of limits and contains the background technical information used.

The proposed regulation specifies daily limits for six contaminants, monthly limits for eight contaminants, "never to exceed" concentrations for three contaminants, non-measurable limits for the most toxic dioxin and furan, pH range and requirements that the effluent is non-acutely lethal to two aquatic species. Chronic toxicity testing is required after the effluent has been demonstrated to be non-acutely lethal for twelve consecutive months.

The loading limits were developed on the basis of Best Practicable Technology (BPT) flow and the normalized average concentrations (MISA monitoring data) of the seven Ontario refineries.

The Best Available Technology (BAT) consultant concluded that the Ontario refineries for most part have BAT in place and that the only way to further reduce the present loadings would be by imposing water conservation which would reduce effluent flow.

The BAT consultant and the Ministry concluded that a BPT flow model, based on standard water usage from a survey of over 200 U.S. refineries, should be the common basis for all seven Ontario refineries. An analysis and comparison of the seven best U.S. refineries to Ontario's refineries in terms of process and treatment technology and effluent quality demonstrated that the pollutant concentration from Ontario refineries were generally lower.

The petroleum refining sector in Ontario consists of seven plants owned by five companies. Under the MISA monitoring regulation, the monitoring of effluents from the seven plants was completed in November 1989 and two reports on monitoring data were published in 1990.

MISA Monitoring

The monitoring results showed that all refineries occasionally exceeded Ontario Effluent Quality Objectives for suspended solids. The objectives for oil and grease, phenolics, zinc and ammonia were also occasionally exceeded by some refineries. Organic compounds such as benzene and toluene (which are typically present in untreated refinery effluents) were found at very low levels at or near the analytical detection limit. All of the plants passed fish toxicity tests except Petro-Canada - Oakville which failed three out of the twelve tests due to elevated levels of zinc and chromium. Since then the four refineries, which had been using zinc-chromium based additives in their cooling towers, have replaced them with phosphate based additives.

Limits Development Background

In order to identify Best Available Technology (BAT) for the petroleum refining sector, the MOE commissioned a consultant to assemble technical design, effluent performance and cost information on available wastewater treatment, in-plant controls, best management practices and other technologies.

The consultant defined BAT as the following:

> *sour water stripping, in-plant treatment of platforming effluent by activated carbon, initial oil and solids removal by the use of API separators, flow equalization, Dissolved Air Floatation (DAF) for further oil removal, biological treatment followed by clarification, and effluent polishing using dual media filters and polishing ponds*

Upon comparison of the defined BAT to the technology presently used in Ontario refineries, it was concluded that Ontario refineries for the most part have BAT in place. This is because Ontario refineries have spent an estimated sector total of 310 million dollars on wastewater treatment equipment since 1974.

A survey of seven Ontario refineries and an evaluation of the monitoring data indicated that the average performance (effluent quality) for seven Ontario refineries was better than the average performance of the seven best refineries identified by the consultant in the U.S.

The conclusion reached by the consultant was that the only way to further reduce the present loadings would be by imposing water conservation which would reduce effluent flow.

In order to evaluate the degree to which water use may be reduced in Ontario refineries, a proven "standard" or "model" was required. Upon investigation, it was concluded that the only detailed studies of water use in the petroleum refining industry were performed by the U.S. Environmental Protection Agency (EPA). The studies were conducted in 1972 and 1976, as a part of the development of Effluent Discharge Regulations. The U.S. EPA flow model, based on a proven "standard" water usage by production processes, was derived from a survey of over 200 U.S. refineries. This flow model is known as the Best Practicable Technology (BPT) flow.

Investigation of flow reduction below U.S. BPT model levels was undertaken by the BAT consultant and the Ministry and it was concluded that setting flow below U.S. BPT levels could not be justified at this time.

By utilizing the BPT flow model, all seven Ontario refineries will be brought to a common level of water use. The promotion of recycle, re-use, and reduction techniques is an important component of any pollution prevention program. The extent to which these techniques may be applied to any industry must be determined. Future detailed studies of water use in Ontario refineries may provide the means to set flow limitations below the BPT levels when the regulation is reviewed in future years.

To evaluate the present performance of Ontario refineries wastewater treatment systems and to determine a basis for effluent quality using BAT, the consultant identified refineries outside Ontario with BAT treatment and achieving high pollutant removal. Seven refineries within the U.S. were selected. The refineries were selected not only on the basis of having BAT and achieving high pollutant removal but because they also had water quality requirements built into their permits. The selected refineries were also of similar size and complexity to those in Ontario.

When the average levels of contaminants in effluent after BAT treatment at the seven U.S. refineries were compared to the average levels found after treatment in the seven Ontario refineries during the 1989 MISA monitoring period, pollutants in effluent emanating from Ontario refineries were generally found at lower levels. From this analysis, it was concluded that the normalized long term average concentrations of seven Ontario refineries should be used for setting effluent quality for limits.

The loading limits were therefore developed on the basis of BPT flow and normalized average concentrations of seven Ontario refineries.

Regulation

The Draft Petroleum Sector Limits regulation specifies all the legal effluent discharge requirements that each refinery must meet. The requirements are related to the quality and quantity of discharges, toxicity testing, flow measurement, and reporting. The regulation will be promulgated under the Ontario Environmental Protection Act (Section 136) and it will come into force within a period of three years, allowing refineries time to implement pollution control and prevention strategies and install the equipment necessary to meet the effluent limits. The Draft Regulation states that sampling points must be established within each refinery on every effluent process stream. Routine monitoring requirements, designed to provide the Ministry of the Environment with assurance that the refineries are meeting the regulation requirements, are tabulated in the accompanying schedules.

The petroleum refining sector Limits regulation specifies:

- Maximum daily allowable discharges for six contaminants (phenolics, volatile suspended solids (VSS), ammonia, sulphides, dissolved organic carbon (DOC), and oil and grease)
- Monthly average plant loading for eight contaminants (total suspended solids (TSS), oil and grease, phenolics, VSS, ammonia, sulphides, DOC, and total phosphorus)
- Never to exceed concentrations for three contaminants (phenolics, DOC and oil & grease)
- Non Measurable (NM) level of two compounds 2,3,7,8 TCDD (tetrachlorodibenzo-p-dioxin) and 2,3,7,8 TCDF (tetrachlorodibenzofuran).
- Limit for the pH (measure of alkalinity or acidity): not to exceed a given range.

- Requirement to carry out acute lethality tests on two species (rainbow trout and Daphnia magna).

- Requirement to carry out chronic toxicity testing on the reproduction and survival of two species (Ceriodaphnia dubia and Fathead Minnow) if the discharger's effluent passes acute toxicity testing for 12 consecutive months.

The capital cost of compliance with the proposed limits is estimated at $57,500,000 and the annual operating cost at $8,600,000.

Impact of the Proposed Regulation

At present, Ontario refineries have to comply with the federal loading limits for five contaminants and the requirement that the effluent should no be acutely lethal to rainbow trout. These requirements are imposed by the federal 1974 Petroleum Refinery Regulations and Guidelines issued under the Fisheries Act. The provincial (Ontario) requirements are spelled out in a Certificate of Approval on a plant specific basis. The number of regulated contaminants varies from one location to another. The requirements are expressed in concentrations of contaminants, which are based on Ontario Effluent Quality Objectives[1]. Some refineries do not have a Certificate of Approval, in which case they have to comply with the federal requirements only.

The implementation of the new MISA limits regulation will improve the present legislation and enforcement in Ontario and beneficially affect the environment for the following reasons:

- Stricter loading limits than required by the existing Canadian or U.S. Federal regulations.

- An estimated reduction of present loadings by nearly 30%.

- Uniformity of legal requirements - the limits will be imposed on all the refineries, not just those with a Certificate of Approval.

- Non acutely lethal requirement for Daphnia magna, in addition to the rainbow trout toxicity criterion, will provide for protection of lower species which are important for fish survival.

- Chronic toxicity requirement will require further improvement of the effluents to prevent long term effects on reproduction and survival of tested species.

- The requirement for non measurable levels of 2,3,7,8 TCDD and 2,3,7,8 TCDF will prevent discharge of highly bio-accumulative contaminants. This will impose the necessity for in-plant controls or process changes.

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[1] Ontario Ministry of the Environment. Liquid Effluent Guidelines for the Petroleum Refining Industry. Toronto, Ontario. September 1977.

Conclusion

The implementation of limits based upon sector average concentrations will bring all Ontario refinery wastewaters to a common level of pollution control, help reduce the variability in effluent quality, and overall, reduce the amount of pollutants entering Ontario waterways.

Although Ontario refineries have been identified as having BAT in place, improvements can be made in the operation of petroleum refining wastewater treatment systems. Steps can be taken to maintain low pollutant concentrations in final effluent and eliminate high daily and monthly concentration fluctuations. Furthermore, as optimum BAT performance is achieved, continued pollutant reductions will occur within the refinery, through the application of reduction, recycle, and reuse technologies and other pollution prevention techniques (ie. best management practices or use of alternate technology).

LIST OF ABBREVIATIONS

4AAP	4-amino-Anti-Pyrine, an analytical test for measuring phenolics as a class or compound
API	American Petroleum Institute
AR	Attached Report
ATG	Analytical Test Group
BAT	Best Available Technology
BAT(EA)	Best Available Technology (Economically Achievable)
BBL	Barrel (unit of measure)
BOD	Biological Oxygen Demand
BPJ	Best Professional Judgement
BPT	Best Practicable Technology
BTX	Benzene, Toluene, and m, o, & p-Xylenes
CAS	Chemical Additive Substitution
COD	Chemical Oxygen Demand
CONCAWE	The Oil Companies' European Organization for Environmental and Health Protection
CPPI	Canadian Petroleum Products Institute
DAF	Dissolved Air Floatation
DOC	Dissolved Organic Carbon
EA	Economic Achievability
EPA	Environmental Protection Agency
FOD	Frequency of Detection
GAC	Granular Activated Carbon
GLWQA	Great Lakes Water Quality Agreement
IGPM	Imperial Gallons per minute (unit of measure)
IJC	International Joint Committee
IRC	Issue Resolution Committee
JTC	Joint Technical Committee
LMDL	Laboratory Method Detection Limit
LSS	Limit Setting Subcommittee
LTA	Long Term Average
MAC	MISA Advisory Committee
MDES	Monitoring Data Evaluation Subcommittee
MIDES	MISA Data Entry Service
MISA	Municipal/Industrial Strategy for Abatement
MOE	Ontario Ministry of the Environment
NM	Non Measurable
NPDES	National Pollutant Discharge Elimination System
NRDC	National Resources Defence Council
NSPS	New Source Performance Standards

LIST OF ABBREVIATIONS continued

OEQO	Ontario Effluent Quality Objective
OPA	Ontario Petroleum Association
OTCW	Once Through Cooling Water
PAC	Powdered Activated Carbon
PACE	Petroleum Association for the Conservation of the Canadian Environment
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
pH	Hydrogen ion
POW	Potentially Oily Water
QA/QC	Quality Assurance/Quality Control
RBC	Rotating Biological Contactors
RMDL	Regulation Method Detection Level
RPR	Reference Production Rate
SAIC	Science Applications International Corporation
SCS	Soil Conservation Service
SMC	Sarnia Manufacturing Centre
TEQ	Toxics Equivalent
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solids
U.S.	United States of America
USGAL	U.S. Gallons (unit of measure)
UV	Ultra Violet
VF_1	Variability Factor (daily)
VF_{30}	Variability Factor (monthly - based on daily monitoring)
VF_4	Variability Factor (monthly - based on weekly monitoring)
VOC	Volatile Organic Carbon
VSS	Volatile Suspended Solids
WWTP	Wastewater Treatment Plant

CHAPTER 1

INTRODUCTION

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1.0 - INTRODUCTION

1.1 - THE MISA INITIATIVE

The Ontario Ministry of the Environment (MOE) initiated the Municipal-Industrial Strategy for Abatement (MISA) Program in 1986[1]. MISA was designed as a regulatory program to reduce water pollution from both industrial and municipal dischargers. The ultimate goal is to virtually eliminate persistent (long-lasting) toxic contaminants from all discharges into Ontario's waterways.

Initially, technology-based effluent limits will be imposed on each discharger as a minimum pollution control requirement. In addition, to protect very sensitive water bodies receiving the discharge, more stringent effluent limits may be superimposed on dischargers on a site-specific basis.

The process to develop technology-based effluent limits involves two phases. In the first phase, effluent monitoring regulations were promulgated. The dischargers were required to monitor their point source effluents at regular intervals according to specific sampling, analytical, and Quality Assurance/Quality Control (QA/QC) protocols and procedures. Information generated by the effluent monitoring regulations produced a database on contaminants discharged across Ontario.

The effluent limits regulations are currently being developed with the participation of stakeholders and the general public. Consultation with stakeholders is facilitated through Joint Technical Committees (JTCs), made up of representatives from the Ministry, Environment Canada, MISA Advisory Committee (MAC) and the affected dischargers. These committees, one per sector, provide an opportunity for the dischargers to have input to the regulation development process.

Review of the regulation is initially provided by MAC. Independent technical and environmental experts sit on this committee, which provides the Minister of the Environment with advice and comments on regulations being developed as well as other MISA matters. All regulations will appear in draft form for a period of at least sixty days to allow for public review and comment, prior to promulgation.

Development of the effluent limits regulations does not end with the promulgation of the regulation. The Ministry is committed to keeping abreast of available pollution reduction technology. The effluent limits regulations will be reviewed at regular time periods and amended, as new technologies become available.

Through this process of on-going evaluation and step-by-step reductions, MISA's ultimate goal to virtually eliminate the discharge of persistent toxic contaminants will be achieved. Such a goal fulfils Ontario's commitment to the protection and improvement of our natural water resources, and is consistent with the provisions of the Canada-Ontario Agreement respecting Great Lakes Water Quality[2] and the Canada-United States Great Lakes Water Quality Agreement[3].

1.2 - THE EFFLUENT MONITORING REGULATION FOR THE PETROLEUM REFINING SECTOR

The effluent monitoring regulation for the petroleum refining sector was designed to provide an accurate and credible status report for priority and conventional pollutants from this industrial sector, and to identify any residual problems for the development of future controls.

The effluent monitoring regulation was developed by the Ministry in consultation with representatives from Ontario petroleum refineries, Environment Canada and MAC through the JTC for the petroleum refinery sector.

As part of the pre-regulation program, a working group of the JTC reviewed an extensive list of studies concerning trace contaminants in oil refinery wastewaters. Generally, these studies indicated that there were no major immediate concerns with respect to the impact of the treated refinery effluents on receiving waters. The studies did, however, indicate that there was a potential for the discharge of a number of substances at environmentally significant levels. It was, thus, determined that, to assess the quantity and the quality of discharges from the petroleum refining sector under everyday operating conditions, all refineries should monitor according to the same schedule.

A review of biological studies indicated discharges of potentially toxic substances. The monitoring regulation required acute toxicity testing for two species, rainbow trout and Daphnia magna.

The specific requirements of the effluent monitoring regulation for the petroleum refining sector are presented in Ontario Regulation 359/88 as amended to Ontario Regulation 696/88[4]. A detailed explanation of the rationale supporting the specific requirements of the effluent monitoring regulation for the petroleum refining sector is also available[5].

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1.3 - EFFLUENT LIMITS REGULATION DEVELOPMENT PROCESS

The MISA Issue Resolution Process was initiated by the Ministry in late 1989 to establish standard procedures and criteria for the development of the effluent limits regulations. These procedures and criteria were required in order to ensure that key MISA concepts (outlined in the original White Paper[1] of 1986) were not open for interpretation and were developed to provide, specific guidelines to the JTCs for the drafting of the regulations, thus enabling the development of regulations for all sectors would be on a consistent and equitable basis.

Early in 1990, special working groups called Issue Resolution Committees (IRCs) were formed. The working groups included representatives of the MOE, industry and municipalities. Environment Canada and MAC were observers, however, they were asked to comment on the proposed limits development process. Their comments and concerns were carefully assessed during the ministry's decision-making process.

The general process described in the IRC final report summary[6] and the IRC report[7] was followed in developing the effluent limits regulation for the petroleum refining sector.

Step 1. Selection of Candidate Parameters for Limits
Under the effluent monitoring regulation, dischargers were required to monitor for a comprehensive list of contaminants. Statistical tests were applied to the monitoring data to identify/confirm which contaminants from that list were absent from the effluents. Those parameters determined to be absent did not qualify as candidates for limits setting.

Step 2. QA/QC Data
The data collected under the monitoring regulation was validated for any errors and then evaluated through QA/QC analysis to establish the reliability and validity of the monitoring database.

Step 3. Statistical Analysis
To establish long term average concentrations (LTAs), distribution, variability factors, outliers, etc. for the selected candidate parameters, additional statistical procedures were used.

Step 4. Selection of Best Available Technology (BAT)
The next step involved the evaluation of available pollution control technologies which could be applied for treatment of selected candidate parameters for limits. A short list of potential technologies and their costs, were identified. The technologies were assessed for their technical viability and for contaminant reduction.

Step 5. Economic Achievability

Information about estimated pollutant removal efficiencies and costs of the various potential BATs, provided in Step 4, was used to derive abatement cost functions which show the relationship between different levels of contaminant reduction and the cost of achieving them. Financial and economic consequences associated with the various levels of control were also estimated. The information on technologies and economic and financial impacts were used when choosing the "best available technology (economically achievable)", BAT(EA), upon which the effluent limits are based.

Step 6. Limits Setting

Once BAT(EA) had been established, discharge limits were set. These will be imposed on the contaminants which the BAT(EA) can treat and at levels which the BAT(EA) can achieve in the Ontario petroleum refineries.

1.4 - COMPLIANCE WITH THE EFFLUENT LIMITS REGULATION

The IRC process also dealt with issues related to compliance with the limits regulation and produced the following recommendations:

1. Under the regulation, dischargers must meet the limits, and ensure that their effluents meet toxicity requirements. The toxicity testing requirements stipulate when and how dischargers must test their effluents.

2. Pollutant loadings are to be determined by multiplying the concentration of the contaminants in the effluent by the rate at which the effluent is discharged. The accuracy of this measurement depends, in part, on the accuracy of the device which is used to measure the flow. Therefore, a level of accuracy and precision for flow measuring devices was set, and dischargers must ensure their equipment is designed and maintained to achieve it.

3. The regulation establishes the terms and conditions of compliance. These specify what dischargers must do in order to demonstrate that the regulation requirements are being upheld. The frequency of monitoring contaminants for the purpose of assessing compliance with the effluent limits is a main component of the regulation compliance requirements. Information gained through compliance monitoring will provide the Ministry and the public with information on the effectiveness of the MISA program.

4. In addition to wastewaters generated as a result of plant processes, contaminated storm water is also discharged from the plant sites. If the storm water is not treated, dischargers will be required to conduct a storm water control study. If the study shows that the surface runoff at a site exceeds the BAT limits for process effluent for that sector, action will be required to control the storm water.

5. Another concern is a situation in which an effluent by-passes the treatment plant and is discharged either untreated or only partially treated. Practices and procedures to eliminate such occurrences were thus identified.

6. The Ministry will continue to report to the public after the limits regulation is promulgated. Reports will provide information on the status of compliance and the status of the individual pollution abatement programs. Reports will also indicate progress toward achieving the MISA goal of virtual elimination of persistent toxic substances.

7. The regulations will be reviewed periodically with a view of establishing more stringent limits.

1.5 - REFERENCES

1. Ontario Ministry of the Environment. Municipal-Industrial Strategy for Abatement (MISA). A Policy and Program Statement of the Government of Ontario on Controlling Municipal and Industrial Discharges into Surface Waters. Water Resources Branch. Toronto, Ontario. June 1986.

2. Canada-Ontario Agreement respecting Great Lakes Water Quality, signed March 6, 1986.

3. International Joint Commission. Great Lakes Water Quality Agreement, with annexes and terms of reference between the United States and Canada. Ottawa, November 22, 1978.

4. Government of Ontario. Ontario Regulation 359/88 as amended to Ontario Regulation 696/88 under the Environmental Protection Act -- Effluent Monitoring - Petroleum Refining Sector. Queen's Park. 1988.

5. Ontario Ministry of the Environment. Effluent Monitoring Regulations for the Petroleum Refining Sector. Toronto, Ontario. July 1988.

6. Ontario Ministry of the Environment. MISA Issues Resolution Process Final Report Summary. Toronto, Ontario. September 1991.

7. Ontario Ministry of the Environment. MISA Issues Resolution Process - Issue Resolution Committee Reports. Toronto, Ontario. June 1990.

CHAPTER 2

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CHAPTER 3

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3.0 - WASTE CHARACTERIZATION INFORMATION DATABASE

This chapter presents information about the sources of data used in developing the regulation, including some discussion about the reliability of the data and the sources.

Waste characterization efforts are described in three parts:

- Pre-regulation Monitoring
- MISA monitoring
- Other Sources

3.1 - PRE-REGULATION MONITORING

Between 1979 and the announcement at the MISA program (1986), the Petroleum Association for Conservation of the Canadian Environment (PACE)* sponsored several major investigations aimed at defining the contaminants in petroleum refinery effluents. These investigations characterized the trace substances (organic and inorganic) present in intake water streams, untreated process wastewaters and refinery effluents. A special study[1] was undertaken to define the fate of organic trace contaminants within the refinery wastewater treatment plant and assessed the variability of trace organic substances in the effluent from two refineries.

On behalf of PACE, in conjunction with the Ontario Petroleum Association (OPA)**, the Ontario Ministry of the Environment (MOE), and Environment Canada, CANVIRO Consultants undertook the pre-regulation study to determine the relationship between biological treatment process operating conditions and the ability of the process to remove trace contaminants.

The project scope was developed in consultation between government and industry. The objectives were to provide data to assist in the development of an effective and workable Monitoring Regulation.

The study had three objectives:

(i) to determine the relationship between trace contaminant concentrations, biotreatment plant operating conditions, and refinery operation (crude throughput, shutdown and upset) for two refineries;

(ii) to provide additional data to allow assessment of the practicability of selecting a surrogate parameter as a measure of trace contaminant removal performance; and,

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* PACE has become the Canadian Petroleum Products Institute (CPPI).

** OPA has become the Ontario Division (OD) of CPPI

(iii) to validate previous studies of trace contaminants conducted on petroleum refinery wastewaters by PACE[1,2] and the American Petroleum Institute (API)[3].

3.1.1 - Sampling and Analysis

In order to meet the objectives of the study, a sampling program was conducted at two preselected Ontario refineries. These refineries, and their effluent treatment facilities, were considered representative of the industry in terms of process complexity, age, configuration, and operation of the biological treatment system.

The sampling programs at Esso Refinery (Sarnia) and Petro-Canada (Oakville) involved collection of a biological treatment plant influent sample and effluent sample on every second day of an eleven day sampling period, resulting in six samples of each stream. Effluent sampling corresponded with the hydraulic retention time in the systems. All samples were manually composited six hour flow proportioned samples. During the sampling period, plant operational parameters and critical refinery operating conditions were documented.

The analytical program focused on a comprehensive list of conventional contaminants, metals, volatile organic compounds, and base neutral extractable compounds (a total of 92 parameters). Previous characterization studies and site specific effluent characterization work studies indicated that the frequency of detection for compounds other than those analyzed was very low.

The analysis of conventional contaminants, and total and volatile suspended solids in the mixed liquor and return sludge, were conducted at CANVIRO's Kitchener laboratory. Trace contaminants (metals, base neutral extractable organics, and volatile organic compounds) were analyzed by CAN TEST Ltd. in Vancouver, B.C.

Quality Assurance/Quality Control (QA/QC) Program

For the purposes of maintaining the accuracy and precision of field and laboratory analysis to ensure scientific credibility, a thorough QA/QC program was conducted. The investigation was under strict quality assurance procedures from the initial step of sample bottle preparation through sample collection, sample transport, analysis and, later, generation and reporting.

As an additional check, effluent samples were collected on one day during one sampling period at each refinery and analyzed at the Ministry laboratory.

MOE Toxicity Tests

Effluent samples were also collected on one day at both the Petro-Canada Refinery (Oakville) and the Esso Refinery (Sarnia) for the purpose of conducting toxicity tests. Twenty-two litre samples were collected each hour during the regular 6-hour effluent sampling routine, resulting in a total sample volume of 132 litres. This sample was received by the Ministry laboratory the day after it was collected.

The toxicity tests were conducted by the MOE laboratory as 96-hour static fish bioassays using juvenile rainbow trout.

Statistical Methods

In order to determine efficient estimates of mean and variance for the influent and effluent data sets for each parameter, it was necessary to identify an appropriate frequency distribution which was representative of the analytical data. When plotted on log normal probability paper, some parameters showed a definite log normal distribution. Other parameters (typically conventional contaminants) had so little variance that sample means and variances for log normal and normal distributions were similar. For consistency, sample means and variances and confidence intervals for all of the parameters were based on a log normal distribution.

In many cases, trace contaminant concentrations in both influent and effluent samples were below the detection limit. For the purposes of calculating sample means and confidence intervals, it was necessary to assume values for those contaminants that were not detected above the minimum compound detection limit. Concentrations of compounds that were non-detectable were arbitrarily set at one half of the detection limit. If, however, a particular contaminant was detected in less than half of the samples, the above procedure was not applied because it would have resulted in a double peaked distribution. Therefore, in these cases, mean and 95 percent confidence range calculations were not conducted.

It should be noted that the small number of samples (6) in most cases did not allow verification of the assumed population distribution. Furthermore, in arbitrarily assuming that non-detectable compounds were present at concentrations equal to one half of the respective detection limits, a bias may have been introduced.

In order to further characterize the sampled streams, the frequency of detection (FOD) of a particular contaminant was also calculated. This number represented the percentage of the total samples taken of a stream in which the contaminant was detected above the minimum detection limit.

3.1.2 - The Results and Conclusions

The results of this study were published in the report: "Sampling and Analysis of Refinery Effluents to Assess Variations in Trace Contaminant Concentrations"[4].

The following conclusions have been drawn from the results of the pre-regulation monitoring program:

1. The biological treatment plants at both refineries studied demonstrated highly efficient removal of trace organic contaminants. The only trace organic detected in effluents from both refineries at a frequency greater than 50 percent were phthalate esters which were also present in field blank samples

and may have been associated with laboratory or field contamination. Volatile aromatic compounds were identified up to 50 percent of the time [benzene (50%), xylenes (44%), toluene (11%) and ethylbenzene (6%)] at near detection limit concentrations in Esso Refinery (Sarnia) effluents and were not detected in Petro-Canada (Oakville) Refinery effluents. Polynuclear aromatic hydrocarbons (PAHs) were not detected in any effluent samples at Esso Refinery (Sarnia). At Petro-Canada (Oakville) Refinery, two substituted PAH compounds (dimethyl and trimethyl naphthalene) were detected in 33 percent of the effluent samples.

2. Effluent quality was similar at both refineries with respect to trace organic contaminants despite significant differences in refinery size and complexity, biological treatment plant design and operation, and influent quality.

3. The effluent quality at the two refineries differed in concentrations of conventional contaminants (suspended solids, phenols, total Kjeldahl nitrogen (TKN) and ammonia) and metals.

4. Because effluent quality in terms of trace organics was similar at both refineries and concentrations were near the detection limits of the analytical methods, no relationship could be identified between trace organic removal performance in the biological treatment plant and the operating conditions in the refinery or biological treatment plant.

5. The results generated from this monitoring program were consistent with those reported in previous studies of petroleum refinery effluents. In general, fewer volatile and base neutral extractable organics were detected, at lower concentrations and at a lower frequency of detection in the present study than in previous studies.

6. A surrogate parameter which would be an indicator of trace contaminant concentrations in effluent could not be identified from the results of this study. Trace organic contaminants were typically not detected in effluents from either refinery. Further, there was little variability in the concentrations of conventional contaminants in effluents from either refinery over the range of conditions encountered.

3.2 - MISA MONITORING

MISA monitoring data for the petroleum refining sector were collected under Ontario Regulation 695/88 and Ontario Regulation 359/88 as amended to Ontario Regulation 696/88. Monitoring under this regulation began on December 1, 1988 and was completed on November 30, 1989. Following this period, only the daily frequency parameters continued to be monitored under the requirements of the monitoring regulation until the limits regulation comes into force.

During the MISA monitoring period, data were collected by industry according to Ministry specifications described in the above regulations. The companies were also required to conduct a quality control program to help validate the monitoring data. Besides flow monitoring and sampling for chemical analyses, the dischargers were required to do toxicity testing on their process effluents and once-through cooling water on two species: rainbow trout and Daphnia magna. Industry contracted commercial laboratories for the trace contaminant analysis and the toxicity testing.

Each refinery reported its monitoring data to the Regional Ministry Office in electronic form, using MISA Data Entry System (MIDES). The regional staff checked data for completeness and transmitted them to the Ministry's central Sample Information System.

The Ministry regional staff closely observed compliance by the companies with the monitoring regulation. They inspected the plants during the monitoring period and conducted audit sampling. The Ministry's laboratory performed audit sample analyses to verify the analytical data collected by the industry. The Ministry also performed two open scan characterizations on each refinery process effluent to identify potential new contaminants in the petroleum refining sector. The results of MISA monitoring were published in two "preliminary" six-month reports.

The first "preliminary" report on monitoring data titled "Preliminary Report for the First Six Months of Monitoring in the petroleum refining sector (December 1, 1988 to May 31, 1989)" was published in December 1989 and included monitoring data for the process effluents only.

The second report on monitoring data, titled "Second Report On The Monitoring Data For The Petroleum Refining Sector", covered the second six months of monitoring (June 1 to November 30, 1989) for process effluent streams. The data for effluents such as once-through cooling water, storm water, landfarm leachate and emergency overflow were provided for the 12 months of monitoring. Both reports were "preliminary" since the database was not validated at that time and many issues such as the handling of data less than the regulation method detection limit, removal of outliers, use of quality assurance/quality control (QA/QC) data were not resolved yet by the IRC process.

The final database is summarized in Appendices A,B,C,D and E of this document.

3.2.1 - Quantity of Analytical Data

A large amount of data has been collected from the refineries in the year of monitoring. The following is the summary for all seven refineries - all data points in the petroleum refining sector - for the period December 1, 1988 to November 30, 1989:

Type of Effluent	Number of Data Points
Process Effluent	35,700
Once-Through Cooling Water	5,725
Storm water	3,934
Landfarm Leachate	1,368
Emergency Overflow	53
Intake Water (optional - not required by regulation)	14,375
Quality Control	17,872
Total	79,027

3.2.2 - Data Validation

The objective of validating the data collected as part of the effluent monitoring regulation for the petroleum refining sector was to ensure the integrity of the information contained in the database. Errors can occur in the handling of over 79,000 data points and data validation was necessary to correct possible errors.

The validity check conducted by the Ministry focused on potential errors in data reporting, sampling or analytical results, since these errors could adversely affect the final data analysis and limits.

The data validation process involved five major steps:

- Verification of Units
- Multiple Record Check
- Sample Types Check
- Review of Remark-coded Data
- Review of Attached Reports

The activities in each of the above-noted steps and findings are presented in the following paragraphs.

Verification of Units

The purpose of this activity was to ensure that the units reported for a particular parameter were consistent during the entire 12-month monitoring period. An error in reporting wrong units could produce a large error in the calculations of loadings or any kind of averages.

Except for one refinery - which reported two types of units for oil and grease in storm water on one day, the units were reported correctly for each parameter throughout the monitoring period.

Multiple Record Check

The Effluent Monitoring database was checked for multiple records, that is if two or more records existed for the same control point, parameter and day. The presence of such multiple records in the database would adversely affect any manipulation of data where calculation of averages or loadings were involved.

The results of this exercise suggest that the database contained many duplicate records mainly for the analytical results. It was determined that either the same value was entered twice or two laboratories did the analysis of the same sample and both results were reported. Upon examining the data and differences between reported data in the latter case, it was decided that if duplicate or multiple records for a particular parameter on a particular day were contained in the database, then the average of duplicate values would be calculated and used in any subsequent data analyses.

Sample Types Check

The purpose of this exercise was to verify that the appropriate sampling procedure had been used to collect samples for analysis of volatile parameters (sulphides, halogenated, non-halogenated and water soluble volatiles). The appropriate sampling procedure for analyses of volatiles is a three grab composite sample (either equal volume - bucket or equal volume - slip stream). Use of an automatic sampler could produce loss of volatiles.

The results of this exercise suggested that all refineries reported the appropriate sampling method for all volatiles except sulphide. Further investigation confirmed that the appropriate sampling method was used but in some cases a wrong code was reported.

Review of Remark-coded Data

The MIDES program allowed the refineries to qualify each data entry with a remark code from a list of twenty-nine codes established by the Ministry. Selected remark codes are shown in Table 3.1. Remark codes were used to highlight problems or uncertainty with the reported data, such as: late data, no data, "less than" values, approximate values, "attached report" explanations, analytical interferences, improper preservation of samples, etc.

TABLE 3.1

REMARK CODES

REMARK CODE	DESCRIPTION
<	Actual amount less than reported
>	Actual amount probably greater than reported
A	Approximate value
<DL	Reported value = MDL: measured amount < MDL (non-zero)
<T	A measurable trace amount: interpret with caution
<W	No measurable response but reported a value
<WE	No measurable response due to dilution but reported a value
AR	Attached report
I	Interference suspected
IC	Interference: colour
IM	Interference: Sample Matrix
N/A (OR !)	No data will be reported: see textual report
LD	Old: sample exceeds maximum storage time
UQC	Data unreliable: possible lab QC problem(s)
!IN	No data: insufficient volume due to inspection
INM	No effluent - no sample available
UCR	Data unreliable: could not confirm by reanalysis

In summarizing monitoring data, the following guidelines were observed:

- All analytical results with remark codes "<DL", "<T" and "<W", "<", ">", "A" or without a remark code are included.
- All other data with the remark codes unlike the ones above are ignored in this review (1.5% of the data), because they represent questionable data.

The commercial laboratories, which were contracted to perform analysis for industry, had to meet certain requirements regarding analytical detection limit. The laboratory method detection limit (LMDL) had to be equal to, or lower than the regulation method detection limit (RMDL). The remark code "<DL" refers to the LMDL.

Table 3.2 shows the total number of data for process effluents with a breakdown of the remark-coded data which were used in this summary.

TABLE 3.2

PROCESS EFFLUENT REMARK-CODED DATA

REMARK CODE	NUMBER OF DATA POINTS	% of TOTAL
"DL"	14,171	39.70
"T"	0	0.00
"W"	13	0.04
"<"	39	0.11
">"	6	0.02
"A"	9	0.03
NONE	21461	61.10
TOTAL	35700	100.00

As can be seen from the Table 3.2, nearly 40 % of process effluent data were reported with the "<DL" remark code, which means that the concentration values for these data could have been somewhere between "0" and the value of the LMDL. For the purposes of calculating averages the concentration values reported as less than the analytical detection limit (coded as "<" or "DL") were assigned the value of LMDL.

Since values coded as "<DL" can also mean that the parameter was not found, the use of the detection limit substitution for a large number of "<DL" values results in averages biased on the high side as well as higher number of "detected" parameters.

Review of Attached Reports

MIDES allowed dischargers to submit written reports in addition to the electronic data submission in cases when problems occurred with the sample or analyses. The record in the electronic data file was marked with the remark code "AR" - attached report (all the remark codes used in the monitoring database are shown in Table 3.1).

The purpose of this step of the data validation process was to identify and investigate all database records containing the "AR" (Attached Report) remark code and decide whether these records should be a part of the database.

The results of this exercise showed that the "AR" code was attached to only a small percentage (1.0%) of records in the database. For those parameters sampled at high frequencies, it was decided that records containing the "AR" code would be ignored during any subsequent analysis since enough valid data points exist to satisfy the requirements of statistical analysis. However, for those parameters sampled at low frequency, the attached reports were investigated. After the investigation, the decision was made to omit all data with a remark code "AR" when manipulating the data set.

3.2.3 - Results of Monitoring

Monitoring data results are presented in the Appendices A, B, C, D, and E.

Quality control data are not considered in this review - a separate report on QA/QC data was published[5].

Loadings are calculated as the product of the flow and concentration.

For continuous streams, such as process and once-through cooling water effluent streams, the daily loading (kg/day) of a parameter is calculated by multiplying reported daily flow by daily concentration (arithmetic mean). The values reported are an average of the daily loadings.

For non-continuous streams (event driven discharges), such as storm water, emergency overflow and landfarm leachate, the mass loading (kg) of a parameter is calculated by multiplying the total volume discharged in a month by the average monthly concentration. The reported values represent the sum of all the monthly loadings (i.e. total mass discharged in twelve months of monitoring).

Appendix A contains summary tables of monitoring results for process effluent streams as follows:

Table A1.0	Process Effluent Streams Conventional and Priority Pollutants Found At All Seven Refineries

Table A1.1 - A1.7	Process Effluent Streams Conventional and Priority Pollutants Found At ... (Each Refinery)
Table A2.0	Process Effluent Streams Monthly Average Flow (m^3/day) For Seven Refineries
Table A3.0	Process Effluent Streams Average Daily Loading (kg/day) For Daily And Thrice Weekly Parameters For Seven Refineries (December 1, 1988 - November 30, 1989)

Appendix B contains summary tables of intake water and once through cooling water data as follows:

Table B1.0-O	Once-Through Cooling Water Effluent Stream Priority Pollutants Found In Four Refineries
Table B1.1-O	Conventional And Priority Pollutants Found In OTCW At Esso Petroleum Canada (Sarnia)
Table B1.1-I	Intake Water Conventional And Priority Pollutants Found At Esso Petroleum Canada (Sarnia)
Table B1.2-O	Conventional And Priority Pollutants Found In OTCW At Petro-Canada Inc., Lake Ontario Refinery - Mississauga Plant
Table B1.2- I	Intake Water Conventional And Priority Pollutants Found At Petro-Canada Inc., Lake Ontario Refinery - Mississauga Plant
Table B1.3-O	Conventional And Priority Pollutants Found In OTCW At Shell Canada Products Limited (Sarnia)
Table B1.3-I	Intake Water Conventional And Priority Pollutants Found At Shell Canada Products Limited (Sarnia)
Table B1.4-O	Conventional And Priority Pollutants Found In OTCW At Suncor Inc. (Sarnia)
Table B1.4-I	Intake Water Conventional And Priority Pollutants Found At Suncor Inc. (Sarnia)
Table B2.0-O	Once-Through Cooling Water Effluent Stream Monthly Average Flow (m^3/day) For The Four Refineries
Table B3.0-O	Once-Through Cooling Water Effluent Stream Average Daily Loading (kg/day) For Priority Pollutants Detected At Four Refineries.

Appendix C contains summary tables for landfarm leachate data as follows:

Table C1.0	Landfarm Leachate Conventional and Priority Pollutants Found At Two Refineries
Table C1.1 - C1.2	Landfarm Leachate Conventional and Priority Pollutants Found At Novacor (Corunna) & Esso Petroleum Canada (Nanticoke)
Table C2.1 - C2.2	Landfarm Leachate Monthly Flow Results For Novacor (Corunna) and Esso Petroleum Canada (Nanticoke)
Table C3.0	Landfarm Leachate Total Mass Loading (kg) For Parameters Calculated At Two Refineries

Appendix D contains summary tables for storm water data as follows:

Table D1.0	Storm water Effluent Streams Conventional and Priority Pollutants Found At Three Refineries
Table D1.1 - D1.3	Storm water Effluent Streams Conventional and Priority Pollutants Found At Novacor, Shell (Sarnia), and Esso (Nanticoke)
Table D2.1 - D2.3	Storm water Effluent Streams Monthly Flow Results For Novacor, Shell (Sarnia), and Esso (Nanticoke)
Table D3.0	Storm water Effluent Streams Total Mass Loading (kg) For Parameters Calculated At Three Refineries

Appendix E contains summary table for emergency overflow data as follows:

Table E1.1 - E1.2	Emergency Overflow Conventional and Priority Pollutants Found At Esso Petroleum Canada (Sarnia) and (Nanticoke)

Concentration Results for Process Effluent Streams

Table A1.0 shows the performance of the petroleum refining sector as a whole for process effluent streams. In this table, the parameters and their frequency of occurrence are shown. The total number of parameters identified at or above detection limit (including data reported as "<DL" to which a value of detection limit was assigned) in the twelve months of monitoring for the entire sector is 80 out of 149 parameters for all monitoring frequencies. This represents the maximum possible, but not confirmed, number of parameters potentially present in the process effluent. The quality and validity of data was evaluated through the QA/QC analysis[5].

Tables A1.1 to A1.7 list the parameters identified in the process effluent streams at each refinery.

The monitoring results showed that all the refineries occasionally exceeded the Ontario Effluent Quality Objectives for suspended solids. The objectives for oil and grease, phenolics, zinc and ammonia were also occasionally exceeded by some refineries.

In the case of Shell Canada Products Limited, the quality of the process effluent reported here should not be regarded as the quality of the final effluent because Shell operated under special circumstances during the monitoring year. Because of the start-up problems with a new clarifier, the process effluent was routed to the potentially oily water (POW) separator for 64 days between June 1 to November 30, 1989. Table A1.5 lists the priority pollutants found in the effluent after the biotreater clarifiers. Effluent from the POW separator was reported as once-through cooling water even though during abnormal or upset conditions it can contain process effluent.

Flow Data

Table A2.0 shows average daily flow data on a monthly basis for process effluent for all seven refineries.

Loadings

Loadings for daily and thrice weekly parameters for all seven refineries are listed in Table A3.0.

Toxicity Testing

Of the 92 samples that were tested with rainbow trout for the entire sector, only 3 out of 12 samples at the Petro-Canada refinery in Oakville did not pass the toxicity test. Chemical analysis of the samples for which the lethality to rainbow trout was observed showed that the concentrations of zinc and un-ionized ammonia in the effluent were the most probable cause of the observed lethality.

Of the 92 effluent samples that were tested for toxicity to Daphnia magna for the entire sector, only 3 out of 12 samples at Petro-Canada Inc., Lake Ontario Refinery, Oakville Plant, and one out of 12 samples at Petro-Canada Inc., Lake Ontario Refinery, Mississauga Plant, did not pass the toxicity test. At the Oakville plant aluminum, chromium, un-ionized ammonia, and oil and grease were measured at levels which caused the observed lethality to Daphnia magna in laboratory tests. A sample of process effluent from the Mississauga refinery had high concentrations of aluminum and chromium, and moderately high levels of zinc which may have contributed to the toxicity of the sample to Daphnia magna.

Further information on the toxicity results can be found in two six month reports on Acute Lethality Data for Ontario's Petroleum Refinery Effluents[6,7].

Intake Water and Once-Through Cooling Water (OTCW)

OTCW data was reported by four refineries. The remaining three refineries use combination of air-cooling and recirculating cooling water.

Intake water monitoring was not required by the monitoring regulation. The refineries which use OTCW systems voluntarily monitored Intake water and reported their results to the Ministry.

Tables listing frequency of detection and concentrations of pollutants in intake water and OTCW (Tables B1.0-O to B1.4-I) are provided in Appendix B.

Table B2.0-O shows monthly average flow in m^3/day for the four refineries that use OTCW.

Table B3.0-O shows average OTCW daily loadings in kg/day for the four refineries. The loadings were calculated based on the average concentration and average flow of all the monitoring data for OTCW and do not take into account any contribution of contaminants from the intake water.

In addition to chemical testing of OTCW, toxicity testing was also performed. None of the nineteen samples collected from the cooling water effluents were acutely lethal to trout. Of the seventeen samples that were tested with Daphnia magna, none were acutely lethal.

Landfarm Leachate, Storm water and Emergency Overflow

Tables listing concentration, flow and mass loadings for landfarm leachate, storm water and emergency overflow effluent streams are provided in Appendices C, D and E respectively. The volumes of effluent discharged and the duration of discharge are provided for these streams because they are event driven. The reported loadings represent the total mass loading for the twelve month monitoring period.

Landfarm leachate was monitored at two refineries only: Novacor and Esso Petroleum - Nanticoke Refinery.

Storm water was monitored at three refineries: Novacor, Shell and Esso Petroleum - Nanticoke.

There were only three events of emergency overflow effluent discharge for the whole sector in the year of monitoring: one at Esso Petroleum - Nanticoke Refinery and two at Esso Petroleum - Sarnia Refinery.

Toxicity testing was not required for these types of effluents.

3.2.4 - QA/QC Analysis of Monitoring Data

Detailed QA/QC analysis of process effluent monitoring data was performed to establish the validity of monitoring data for use in the limit setting process. The results of the QA/QC analysis were published in a separate report.

During the QA/QC assessment of monitoring data, 46 of the 80 "detected" parameters did not pass statistical selection test. They were eliminated from further consideration since (at a 95% confidence level) 90% of the reported values were less than the value of the RMDL. Of the remaining 34 parameters, the presence of 18 parameters was confirmed at quantifiable levels.

3.2.5 - Conclusions

The following conclusions have been drawn from the results of MISA monitoring and the QA/QC analysis of Monitoring Data:

1. The amount and quality of analytical data collected over the twelve months of monitoring indicate that a good database was established for the petroleum refining sector. This database appears to be satisfactory for use in setting the effluent limits.

2. In the twelve months of monitoring, 80 out of 149 parameters were "detected" at or above the LMDL across the sector for all monitoring frequencies. The LMDL in many cases was lower than the RMDL.

3. Detailed QA/QC analysis of monitoring data shows that only 18 of the above 80 parameters (mostly conventionals) were consistently found in refinery effluents at quantifiable levels.

4. Most metals and trace organics were occasionally detected and when detected, they were at or very close to the LMDL.

5. Effluent quality from all the refineries was similar, with regards to the content of metals and trace organic contaminants.

6. Although surrogate relationship between trace organic removal and conventionals had not been statistically established, it was found that the refineries with lower levels of conventional contaminants also have lower levels of trace organic contaminants.

7. With the exception of one refinery, the effluents from Ontario refineries were non-toxic to fish. The positive toxicity tests were related to the certain chemical additives which are no longer used at the refinery in question.

8. Two open scan characterizations performed by the Ministry laboratory did not detect any new contaminants in excess of the 149 parameters.

3.3 - OTHER SOURCES

Other sources of data were also reviewed and these included:

- U.S. EPA Petroleum Refining Point Source Category[8,9].
- PACE reports [1,2,10,11,12,13].
- API report[3].

3.4 - REFERENCES

1. Petroleum Association for Conservation of the Canadian Environment (PACE). Evaluation of the Variability of Trace Organic Substances in Petroleum Refinery Effluents. Report prepared for Petroleum Association of Conservation of the Canadian Environment, PACE Report No. 85-7, Ottawa Ontario.

2. Petroleum Association for Conservation of the Canadian Environment (PACE). Survey of Trace Substances in Canadian Petroleum Industry Effluents. Report prepared for Petroleum Association for Conservation of the Canadian Environment, PACE Report No. 81-4, Ottawa, Ontario.

3. American Petroleum Institute (API). Refinery Wastewater Priority Pollutant Study - Sample Analysis and Evaluation of Data. Publication No. 4346. Washington, D.C. 1981.

4. Ontario Ministry of the Environment. Sampling and Analysis of Refinery Effluents to Assess Variations in Trace Contaminant Concentrations. Water Resources Branch, January 21, 1987.

5. Ontario Ministry of the Environment. Report on the Analysis of the Quality Assurance and Quality Control Data for the Petroleum Refining Sector. Toronto, Ontario. July 1992.

6. Ontario Ministry of the Environment. Acute Lethality Data for Ontario's Petroleum Refinery Effluents Covering the Period from December 1988 to May 1989. Toronto, Ontario. June 1990.

7. Ontario Ministry of the Environment. Acute Lethality Data for Ontario's Petroleum Refinery Effluents Covering the Period from June 1989 to November 1989. Toronto, Ontario. December 1990.

8. The United States Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for Petroleum Refining Point Source Category. April 1974.

9. The United States Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Petroleum Refining Point source Category. October 1982

10. Petroleum Association for Conservation of the Canadian Environment (PACE). Survey of Trace Substances in Canadian Petroleum Industry Effluents. Report prepared for PACE, Report No. 81-4. Ottawa, Ontario.

11. Petroleum Association for Conservation of the Canadian Environment (PACE). Investigation of the Potential Carcinogenic Activity of Oil refinery Effluents. Prepared for PACE, Report No. 85-4. Ottawa, Ontario.

12. Petroleum Association for Conservation of the Canadian Environment (PACE). The Significance of Trace Substances In Petroleum Industry Sludges Disposed of on Land: A Literature Survey. Prepared for PACE, Report No. 83-2. Ottawa, Ontario.

13. Petroleum Association for Conservation of the Canadian Environment (PACE). Evaluation of the Variability of Trace Organic Substances in Petroleum Refinery Effluents. Prepared for PACE, Report No. 85-6. Ottawa, Ontario.

CHAPTER 4

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

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4.0 - BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE (BAT(EA))

In June of 1986, the Ontario Ministry of the Environment (MOE) introduced the Municipal Industrial Strategy for Abatement (MISA) program to achieve the ultimate goal of "... the virtual elimination of toxic contaminants in municipal and industrial discharges into waterways."[1]. This goal was, in part, to be achieved by "increasing the emphasis on control technology ..."[1] through the development of effluent limits based upon the use of BAT(EA).

4.1 - BEST AVAILABLE TECHNOLOGY (BAT)

The method by which BAT technology was determined for the petroleum refining industry, was consistent with procedures outlined in the MISA Issue Resolution Committee report[2]. The BAT Subcommittee consisting of representatives from the MOE, industry and Environment Canada, was formed and the subcommittee was charged with a task to recommend to the Joint Technical Committee (JTC) selected BAT options for economic assessment.

The BAT Study

In order to identify BAT, the MOE commissioned a consultant to assemble the technical design, effluent performance, and cost (capital and operating) information on available wastewater treatment, in-plant controls, best management practices, and other technologies, with special emphasis on pollution prevention measures.

The BAT Subcommittee was involved in the preparation of the terms of reference for the BAT study.

It was decided that the BAT study be divided into two studies carried out simultaneously. The first study was to develop a survey of wastewater treatment technologies available within the United States of America or U.S., Europe, and elsewhere. The second study was to document the current status of plant operations and wastewater treatment systems in Ontario refineries. In this second study, the consultant was required to compile details about each Ontario petroleum refinery including:

- water use, reuse, and recycle
- flow of wastewater per unit production
- specific manufacturing processes, products, and production capacity and rates
- technical specifications and performance efficiency for in-plant and end-of-pipe treatment systems
- raw materials
- wastewater sources, characteristics, and quantities
- in-plant process changes and raw materials substitutions that have resulted in contaminant reduction

- best management practices
- waste management practices and other non-water quality impacts
- capital pollution control expenditures and operating budgets/costs

In addition, the consultant was to compile similar information for refineries in Canada, outside Ontario.

Upon completion of a worldwide and Canada-wide inventory of available technologies, the consultant was to identify a short list of technology trains which were to be evaluated for potential application in the Ontario petroleum refining sector. According to the Terms of Reference for the BAT studies, the "short" list of recommended BAT options had to meet following criteria:

- at least one technology train that produces an effluent which is non-lethal to Rainbow trout and Daphnia magna
- the BAT selected by the U.S. Environmental Protection Agency (EPA) for setting limits in the petroleum refining point source category
- a technology train that utilizes the best technologies currently in use at Ontario petroleum refineries
- and if possible one technology train consisting of any technologies or combination of technologies which advances the petroleum refining sector towards the goal of the virtual elimination of persistent toxic contaminants from discharges into Ontario's waterways

After identifying a short list of potential technology options, the consultant was to collect additional details on the design, capital and operating costs, energy, maintenance and waste management requirements in order to evaluate the technical viability of options and feasibility of their implementation in the Ontario refineries.

The BAT Consultant

In July of 1990, the MOE put forth a request for tenders. The submitted proposals were reviewed by the Ministry and BAT subcommittee. As a result of this review both contracts were awarded to Science Applications International Corporation (SAIC), with sub-contractors Apogee Research International Ltd. and Amendola Engineering. The two studies, which were conducted in parallel, began in August 1990 and concluded in January 1991. The results of the consultants' studies were published in the report entitled "Best Available Technology for the Ontario Petroleum Refining Sector"[3]. The report consists of three parts. Part I covers the inventory of technologies, evaluation of technologies and costing information. Parts II is a report on the Ontario refineries and Canadian refineries outside Ontario. Part III is related to the best available treatment technology for effluents containing dioxins and furans.

Since the consultants' studies provided the basis for the selection of BAT and consequently the development of limits, it is necessary to provide here the highlights of the consultants' report which lead to the decisions made by the BAT Selection and Limits Setting Committees.

4.1.1 - Inventory of Available Technologies

In developing the inventory of wastewater treatment technologies, the consultant categorized the available treatment technologies into in-plant controls, end-of-pipe treatment, advanced treatment, and pollution prevention measures. The technologies were identified from the consultant's knowledge and technical literature reviews. A list of the identified treatment technologies and pollution prevention measures is presented below under their respective category.

Wastewater Treatment Technologies

In-Plant Controls: steam stripping of volatiles, spent caustic/acid neutralization, catalytic reformer wastewater treatment, chemical precipitation of metals

End-of-Pipe Treatment: equalization, chemical treatment, supplemental oil removal (dissolved air floatation (DAF) or parallel plate interceptor), biological treatment (oxidation ponds, aerated lagoons, trickling filters, rotating biological contactors (RBC), activated sludge), effluent polishing (polishing ponds or filtration (single, dual, or multi-media))

Advanced Treatment : granular activated carbon (GAC), powdered activated carbon (PAC), ultrafiltration, reverse osmosis, ozone and ozone/ultraviolet radiation (UV), vapour compression distillation

Pollution Prevention Measures

Pollution prevention measures, in general, reduce the amount and/or toxicity of waste. These measures may include source control, chemical additives substitution, reuse and recycle, and process changes. Pollution prevention can be achieved by implementing simple, effective best management practices (BMP) or by complex and costly measures such as process changes.

Discussed under the broad category of pollution prevention are the following sections which address:

A) Source control - wastewater reduction
B) Cooling water systems, and
C) Storm water management

A) Source Control

Source control measures can significantly reduce the amount of effluent and contaminant load discharged from refineries. Such measures include wastewater reduction, reuse and recycle techniques.

Along with several general measures to reduce effluent flow, major wastewater reduction techniques address wastewater segregation, boiler condensate recovery, and treated effluent reuse. The reduction techniques are briefly described below:

> *Wastewater Segregation* Segregation of a refinery's less polluted wastewaters is important to allow for reuse of wastewaters with little or no treatment. Segregation of severely contaminated streams, such as sour water, provides the opportunity for pretreatment, thus reducing the effects of dilution and contamination of the overall combined process wastewater stream. The wastewaters can be divided into three groups, by level of contamination. The first stream is high-quality and is suitable for reuse with only minimal treatment, if any. The second stream has low total dissolved solids (TDS) and requires some treatment prior to reuse, and the final stream, which has high TDS, is not suitable for reuse and requires complete treatment before discharge.
>
> *Boiler Condensate Recovery* Boiler steam condensate recovery and reuse can also significantly reduce the amount of boiler circuit wastewater. Specific measures include the following:
>
> - Increase of condensate recovery by the "installation or expansion of piping systems to collect steam lost by overheating, tracing, tank heating, traps, and leaks"
> - Reduce vent losses by the "elimination of vents at process units, turbines and steam traps"
>
> *Treated Effluent Reuse* For high quality waste streams, the wastewater may be suitable for direct reuse in cooling systems or for steam generation without treatment. Other examples of reuse (with little or no treatment) include using sour water as make-up for desalters, firewater, service water and wash water, pump gland cooling, and other machine cooling processes. Once through cooling water can be reused as make-up for desalters, cooling towers, or as process water.

B) Cooling Water System

Historically, the primary factor considered in selecting cooling water systems was the availability of water and its associated cost. However, impacts of thermal discharges, water conservation, and the attainment of discharge limitations have also become relevant considerations. The advantages and disadvantages of different cooling systems are presented in Table 4.1.

Although cooling water can be greatly reduced by converting to air cooling systems, this may be impractical or uneconomical for some refineries due to space availability and the orientation of the heat exchanger systems.

Once Through Cooling Water (OTCW) Systems In OTCW systems, due to the use of chlorine and chlorine derivatives as additives, dechlorination using sulfide or sulfite compounds may be necessary to remove residual chlorine. In recent years, as concerns about the environmental impacts of chlorine and chlorination by-products have arisen, the use of bromine and bromine compounds for OTCW treatment has also received consideration.

Cooling Tower Systems There are several methods available to minimize cooling tower blowdown streams. According to a previous study by the consultant on wastewater reuse and recycle in petroleum refineries, cooling tower blowdown can contribute up to one-third of total refinery wastewaters. Of the 12 plants reviewed for improvements in the study, cycles of concentration ranged from 1.1 to 9.5, with an average of 4. Pretreating raw water to improve the quality of the influent which in turn will significantly increase the cycles of concentration in cooling towers.

The toxicity of the blowdown can also be reduced. Recirculating water treatment chemicals containing toxic zinc and chromate compounds can be replaced with less toxic organic compounds.

TABLE 4.1

ADVANTAGES AND DISADVANTAGES
OF DIFFERENT TYPES OF COOLING SYSTEMS

FACTOR	OTCW	COOLING TOWER	AIR COOLING
Noise	none	low	high
Cold weather plumes	none	potential problem	none
Water Contamination Potential from Leaks	high	moderate	none
Soil Contamination Potential from Leaks	none	none to low	moderate
Air Contamination Potential	none	moderate	moderate
Cooling Efficiency	high	high	low to moderate
Energy Required	moderate	high	high
Maintenance and Labour	low	high	low
Potential for Impact for Thermal Shock to Fish	moderate to high	none	none
Potential for Impact of Water Treatment Chemicals	moderate	moderate*	none
Costs	low	high	high

* Provided that zinc and chromium based additives are not used.

C) Storm water management

Storm water management at petroleum refineries can have a significant bearing on the mass discharge of conventional and toxic pollutants to receiving waters. In addition to increasing wastewater volumes, storm water also often contributes high levels of total suspended solids (TSS).

Under ideal circumstances, all storm water should be segregated into the categories identified in Table 4.2 and treated or discharged as indicated.

TABLE 4.2

PETROLEUM REFINERY STORM WATER MANAGEMENT

REFINERY AREA	STORM WATER MANAGEMENT
Immediate process areas	Collection and co-treatment with refinery process wastewaters.
Developed areas of refinery, but outside immediate process areas	Segregation, collection and diversion to storm water holding pond equipped with oil baffles and skimmers. Controlled discharge after examination and testing.
Undeveloped areas	Segregation and direct discharge.

Storm water segregation can easily be incorporated into "grass-roots" refineries, however, segregation at existing refineries may be difficult. Segregation measures may include sloped or curbed process unit pads, individual or discreet drain and piping systems, and holding ponds for testing and controlled releases of wastewater to treatment systems or direct discharge points.

4.1.2 - Preliminary BAT Options

Based on a preliminary analysis at the beginning of the consultant's project, nine options were identified for the regulation of process wastewater, three for OTCW systems, three for cooling tower systems, and two for storm water. These options were identified prior to the collection of data, and prior to evaluating the technology options as to whether they meet the definition of a demonstrated technology, which is as follows:

> "A technology can be considered a demonstrated technology if data on the technology is available and that data can be used to predict, with a reasonable degree of confidence, the reliability of the technology and the performance of the technology with respect to contaminant reductions and effluent variability at any plant in the sector or sub-sector, given the expected variability between plants, and could be successfully retrofitted into existing facilities with a reasonable degree of confidence".

The original list of options was as follows:

Process Wastewater

Option 1	The technology train is equivalent to the U.S. EPA BPT[*]/BAT limits option (for both flow and concentrations) with the addition of the in-plant treatment of catalytic reformer scrubber wastewater with GAC.
Option 2A	The technology train is equivalent to option 1 regarding the technology train but the performance is based on the average flow and average effluent concentrations for all refineries in Ontario.
Option 2B	The technology train is equivalent to option 1 and 2A except that the flow is based on 50% of the calculated BPT flow[**] (that is, the same flow ratio as in the Nanticoke refinery) and the average effluent concentrations of all refineries in Ontario.
Option 3	The best refinery in the world. Based on available information, this is Esso-Nanticoke refinery and the limits would be based on the performance of Nanticoke refinery.
Option 4	The technology that produces non-toxic effluent. Currently, all Ontario refineries are passing acute toxicity tests. Therefore, this option could be the same as options 1, 2A, 2B, and option 3.

---

[*] BPT - Best Practicable Technology.

[**] BPT flow is a model flow developed by the U.S. EPA and it will be explained in more detail in Chapter 5.

Option 5A1 The technology that moves the sector toward virtual elimination of toxics in the effluent by the addition of advanced treatment technologies. In option 5A1, this goal would be achieved by adding to option 2B:

- Steam stripping in-plant for volatile organic compounds (VOC) control,
- Chemical precipitation for metals removal, and
- GAC for end-of-pipe filtration following the biological treatment plant.

Option 5A2 The technology that advances the sector toward virtual elimination of toxics in the effluent by adding to option 2B:

- Steam stripping in-plant for VOC control,
- Chemical precipitation for metals removal, and
- PAC addition to the activated sludge in the biological treatment process.

Option 5A2 Modified would advance the sector toward the virtual elimination of toxics in the effluent by adding PAC in the biological treatment process in addition to option 2B (steam stripping and chemical precipitation are not included)

Option 5B would advance the sector toward zero discharge of effluent by adding (to existing treatment systems) evaporation technology using vapour compression distillation with condensate recycle.

OTCW System Options

Option 1 continues with the existing technologies employed at each refinery.

Option 2 incorporates improvements into the existing systems as described below:

- Dechlorination of OTCW effluents by adding sulfide or sulfite compounds.

- Leak detection by the installation of automated detection systems for identification of VOC and/or oil streams.

- BMP for the control of leaks and spills.

Cooling Tower System Options

Option 1 continues with existing cooling tower system and with existing refinery practices.

Option 2 incorporates improvements as described below:

- Eliminates toxic chemical additives to the cooling tower water.
- Increases cooling water recirculation to the range of 4-6 cycles.

Option 3 converts all cooling tower systems to air cooled systems resulting in zero cooling water discharge to surface waters.

Storm water Options

Option 1 continues existing refinery practices.

Option 2 complete segregation of storm water, similar to Esso - Nanticoke where only storm water falling in process areas is routinely treated.

Since the cost analyses were also completed prior to the collection of data and prior to determining which options were actually demonstrated for use in this industry, cost data for all of the above options are included in Part I, Appendix A of the BAT study report.

4.1.3 - Performance Assessment of Technologies

A worldwide survey of potential sources of performance data for the above technologies was conducted in order to evaluate the relevance of each technology to wastewater treatment in Ontario refineries. To narrow the scope of the search and to ensure the suitability of performance data, only data obtained from operating refineries of similar size and complexity to that of Ontario refineries or from other sources which could be directly applied to refineries in Ontario, were utilized. Potential sources of performance data included government agencies, industrial associations, technical literature, and technical information databases.

The search for performance data focused on Europe and the following countries; Canada, the United States, and Japan. For each country, the investigation began with a review of any present legislation governing petroleum refining operations. In conjunction with the legislative review, industrial groups were also contacted.

Japan

From the information that could be obtained from Japan under the terms of the project, it was determined that Japan does not have a formal regulatory initiative for their petroleum refineries.

The Japanese refining industry utilizes source control as an integral part of pollution prevention. Treatment technologies are similar to those found in Ontario and U.S. refineries.

Water pollution is controlled in Japan under the Water Pollution Control Law. This law stipulates effluent water quality limitations and categorizes public water areas, including rivers, lakes, harbours and coastal sea, and the water lines connected to them.

These standards for effluent water under the Japanese Water Pollution Control Law are as listed below:

STANDARDS RELATING TO HUMAN HEALTH	VALUE	UNIT
Cadmium	0.1	mg/l
Cyanide	1.0	mg/l
Organic phosphorus	1.0	mg/l
Lead	1.0	mg/l
Hexavalent chromium	0.5	mg/l
Arsenic	0.5	mg/l
Total mercury	0.005	mg/l
Alkyl mercury	not detectable	
PCB	0.003	mg/l

STANDARDS RELATING TO LIVING ENVIRONMENT	VALUE	UNIT
pH (effluent to coastal sea)	5.0-9.0	
(others)	5.8-8.6	
BOD	160	mg/l
COD	160	mg/l
Suspended solids	200	mg/l
n-Hexane extract		
• mineral oil	5	mg/l
• animal/vegetable oil	30	mg/l
Phenols	5	mg/l
Copper	3	mg/l
Zinc	5	mg/l
Dissolved iron	10	mg/l
Dissolved manganese	10	mg/l
Chromium	2	mg/l
Fluorine	15	mg/l
Coliform	3000	MPS/100ml

The concentrations specified in the above standards are much higher than the concentrations of the corresponding contaminants in Ontario refineries effluents.

The consultant was not able to provide any performance data from the Japanese refineries therefore, Japan was eliminated from further examination.

Europe

In European petroleum refineries, water discharge regulations are promulgated and monitored at the national, provincial, and local levels. In addition, national governments follow the recommendations of the Paris Commission, and the directives of the European Commission.

Overall, controls and standards for conventional pollutants emitted by refineries vary widely in European countries and in general, discharge permits are designed and negotiated on a plant-by-plant basis. The monitoring of toxic pollutants in refinery effluents is limited to mercury and cadmium, as required by the European Commission directives. Other toxic pollutants, such as organics and heavy metals, are monitored by government authorities in only a few countries. Examples of regulated pollutants and typical standards for the Paris Commission, The Netherlands, United Kingdom, and Germany are shown in Table 4.3.

The average concentrations of oil, chemical oxygen demand (COD), sulfide, ammonia and phenols in Ontario refineries effluents are lower than the concentrations shown in Table 4.3.

In an attempt to yield more consistent and detailed information, CONCAWE (the oil companies' European organization for environmental and health protection) was contacted. CONCAWE monitors and reports the discharge of pollutants from European refineries, however, the information is developed and presented as a gross pollutant loading to the environment. Thus, accurate and reliable performance data from individual refinery wastewater treatment systems in European refineries could not be obtained.

TABLE 4.3

EXAMPLES OF EUROPEAN STANDARDS

Paris Commission[1]	
Oil concentration	5 mg/l (ave.)
Oil concentration (ballast water)	20 mg/l (ave.)
Total oil discharged	3 g/tonne of refinery capacity (ave.)
Netherlands[2]	
Oil concentration - old refineries	30 mg/kg (ave.)
Oil concentration - new refineries	10 mg/kg (ave.)
Oil concentration - ballast water	20 mg/kg (spot sample)
Germany[3]	
Proposed:	
COD	120 mg/l (grab sample)
Total hydrocarbon	2 mg/l (grab sample)
Organic Cl	0.1 mg/l (grab sample)
Ammonia	10 mg/l (grab sample)
Sulfide	0.6 mg/l (grab sample)
Phenols	0.15 mg/l (grab sample)
United Kingdom[4]	
Typically Controlled Pollutants:	
Oil & Grease concentration	20 mg/l (example)
Temperature	variable
Suspended Solids	variable
Copper	variable
Sulfides	variable

Sources:

[1] Paris Commission - Procedures and Decisions Manual. Feb. 1989, pp. 3-4.

[2] Broseliske, G.H., Ministry of Public Works, Institute for the Purification of Water, 1990. Correspondence. Nov. 22, 1990, p.3.

[3] Triennial Report on Discharges from Refineries in 1987. 1989. Eleventh Meeting of the Paris Commission, Dublin, June 19-22, 1989.

[4] Bird, Dr. P., National Rivers Authority, 1990. Correspondence. Dec. 13, 1990.

Current Status in Ontario

The consultant began the study on the current status of wastewater treatment systems within Ontario petroleum refineries by developing a detailed questionnaire on present refinery and wastewater treatment operations. Copies of the questionnaire were sent to each refinery to be answered in preparation for site visits which were conducted by the consultant in conjunction with the Ministry. During each site visit, the questionnaire was reviewed with refinery operations staff in order to verify the accuracy of the information.

From the information collected through the questionnaire and then confirmed by the site visits the following facts were established:

- The seven refineries all use modern wastewater treatment methods.
- Wastewater is treated along conventional lines: API separators, air floatation or dual media filtration followed by equalization basins, biological treatment and clarification before discharge.
- Storm water is segregated in all cases, but not always in the same manner.
- Ballast water in all cases receives full biological treatment.

Final dual media filtration of the effluent plus ponding is practised in one plant while another refinery uses GAC mainly for periods when the storm water system is overloaded. On occasion, the filters are used to treat process effluent.

The refineries are presently utilizing a number of methods for recycling and reusing water:

- The use of stripped sour water for desalter make-up.
- The recycling of steam condensate.
- The recycling of pump and compressor gland water.
- The minimization of cooling tower blowdown.

Details of the Ontario refineries' survey are covered in Part II of the BAT study report[3].

Canada - Outside Ontario

The Canadian Federal Petroleum Refinery Effluent Regulations and Guidelines, developed under the Federal Fisheries Act, were enacted in January of 1974. The regulations apply to all new refineries that started operations on or after November 1, 1973.

The guidelines are less stringent and are not enforced, but are statements of practice to maintain the "spirit of the law" for refineries built prior to November, 1973.

The regulations and guidelines were based upon the BPT then in use. They were intended to ensure a minimum standard of performance across the country and to eliminate "pollution havens". The allowable discharges for the deposit of substances are based upon crude oil throughput and are generally expressed in contaminant loadings (kilograms per 1000 barrel/day of crude).

The effluent quality objectives for Alberta and British Columbia were also reviewed.

The province of Alberta has effluent quality objectives (concentrations) for hexavalent chromium, cyanide, lead, mercury, zinc and nickel. During the year of monitoring, the average concentrations of these compounds in Ontario refineries effluents were below the objectives for Alberta.

The province of British Columbia has effluent quality objectives for the following compounds: oil, phenols, sulfide, ammonia, TSS, cyanide, total chromium, lead, zinc, copper, nickel, phosphorous and DOC. With the exception of zinc and DOC, the concentrations of these compounds in the Ontario refineries' effluents were below the objectives for British Columbia.

Utilizing information obtained from across Canada[4], the consultant reviewed the data for 22 refineries outside of Ontario to determine if any of these plants is employing technology or obtaining end-of-pipe results superior to those in Ontario.

The type of wastewater treatment system and the frequency of compliance with the federal regulations, was obtained for each of the 22 Canadian refineries. Elimination of the refineries which did not fit the selection criteria for BAT (eg. similar size process and complexity) narrowed the choice to two plants; Shell Canada Montreal and Ultramar St. Romuald, Quebec. The latter plant employs a simple type aerated lagoon without recycled sludge. This system is not comparable to the more efficient return activated sludge treatment systems used throughout Ontario. Therefore, Ultramar St. Romuald was ruled out, leaving Shell Montreal for further consideration.

The United States

In the United States, the current sector-specific regulations can trace their beginnings to the passage of the Federal Water Pollution Control Act Amendments of 1972. These Amendments changed the emphasis of U.S. water protection from water quality based protection to a uniform system of technology-based standards for industrial sources.

One of the major provisions of the 1972 amendments was the establishment of the National Pollutant Discharge Elimination System (NPDES) which created the existing permit requirements for industries discharging into U.S. waters.

The U.S. Petroleum industry was one of the major industries targeted as requiring national technology-based effluent limitations guidelines and standards. After a number of administrative and legal appeals, the regulations were established in 1982, and modified into their current form in 1985. The U.S. EPA has promulgated the petroleum industry regulations within Title 40 of the U.S. Code of Federal Regulations at Part 419 (cited as 40 CFR 419).

From the population of refineries throughout the U.S., refineries were selected in terms of having similar size and similar production processes to the Ontario refineries. A final seven were selected as the "best" performing refineries in the U.S., because they are subject to chemical-specific State water quality standards, toxicity testing requirements, and had installed treatment beyond those established by the U.S. EPA definition of BAT (e.g. filtration of effluent, activated carbon treatment, etc.). A list of the refineries selected is given below:

Pacific Refining;	Hercules, California
Chevron USA;	Richmond, California
Chevron USA;	Salt Lake City, Utah
BP Oil;	Ferndale, Washington
Ashland Petroleum;	Canton, Ohio
Mobil Oil;	Paulsboro, New Jersey
Conoco Inc.;	Commerce City, Colorado

4.1.4 - Demonstrated Technologies

The consultant used the following criteria to select demonstrated technologies:

- the technology is used in the petroleum refining sector or the technology could be transferred from a similar industrial sector that produces effluents with similar characteristics
- the technology can be retrofitted in the existing facilities
- the technology has been in commercial use for more than one year
- the technology for which design, sizing and costing information is available or it can be developed

Non-demonstrated technologies

Based upon the analyses of the available performance data and the above criteria, the following is a list of technologies that were not considered to be demonstrated for use in Ontario:

Process Wastewater

- *Steam stripping for specific toxic organics removal* Data for this technology do not show performance to be better than typical secondary treatment.
- *Chemical precipitation for metals removal* Data for this technology also fails to demonstrate better performance than typical secondary treatment.
- *Granular and powdered activated carbon treatment* There is insufficient data to predict performance with a satisfactory level of confidence for Ontario refineries. In addition, data for this technology does not show performance to be better than typical secondary treatment.
- *Membrane technologies* Data available for this technology is also insufficient to predict performance with sufficient confidence needed for a BAT analysis.
- *Ozone and ozone/UV* Data available for this technology is also insufficient to predict performance with sufficient confidence needed for a BAT analysis.
- *Evaporative Technologies* There is insufficient information to determine the reliability of this technology and to determine whether this technology can be successfully retrofitted.
- *Source Control* Based upon information obtained, it is believed that although extensive flow reductions can be attained, it cannot be substantiated that all Ontario refineries can meet the extensive flow reduction achieved by Esso Nanticoke. Nanticoke has achieved its low flow by incorporating low water usage techniques into its original design; not all of these techniques may be retrofittable, including complete sewer segregation and air cooling. A complete and detailed water balance of each Ontario refinery would be needed to determine whether retrofit flow reduction schemes could be used to achieve Nanticoke's level of low water usage.

Cooling Water: For once through cooling and cooling tower systems, 100% air cooling has not been demonstrated because it is not believed that this technology can be successfully retrofitted into older refineries. This is primarily due to space availability and retrofitting problems with existing process technology.

Storm water: Complete segregation is also not a demonstrated technology. It is based upon technology used at new refineries, and it cannot be demonstrated that extensive retrofitting can be accomplished at older refineries.

Demonstrated Technologies

The available performance data are presented in Table 4.4.

TABLE 4.4

AVAILABLE PERFORMANCE DATA

POLLUTANT (mg/l)	OPTION 1: U.S. BPT/BAT LIMITS	OPTION 2A: AVERAGE OF 7 ONTARIO REFINERIES	OPTION 2B: BEST ONTARIO REFINERY (NANTICOKE)	AVERAGE OF 7 BEST U.S. REFINERIES	BEST U.S. REFINERY	OPTION 5A2: (MODIFIED)*
TSS	10	22.4	7.0	31	11	41
COD	100	49.2	30.6	85	58	145
Oil & grease	5	2.4	1.8	4.08	1.79	1.1
Ammonia	6	2.0	0.34	5.21	0.10	4.0
Sulfide	0.10	0.09	0.004	<0.03	<0.03	N/A
Phenolics (4AAP)	0.100	0.011	0.004	0.047	0.0049	0.018
Total Chromium	0.250	0.112	0.009	0.028	0.010	0.100
Lead	0.024	0.004	0.003	<0.02	<0.005	0.018
Zinc	0.231	0.290	0.027	0.09	<0.005	0.14
Benzene	0.002	0.0007	0.0002	<0.005	<0.004	<0.04
Toluene	0.002	0.0007	0.0002	<0.005	<0.004	<0.01
Naphthalene	<0.001	<0.001	<0.001	<0.003	<0.001	<0.010
Copper	N/A	0.009	0.006	<0.012	<0.006	N/A
Nickel	N/A	0.010	0.006	<0.08	0.036	N/A

▨ concentrations used in U.S. EPA BAT/BPT limits

NOTE: U.S. data are results of various surveys or monitoring under site specific permit requirements.

Where there is a "<" sign followed by a number, it means that the compound was not detected at the present detection limit.

* The performance of option 5A2 could theoretically produce a better quality effluent than option 2A, however, the obtained performance data does not confirm this expectation.

From the summary of available performance data for all technology options considered, the following conclusions were drawn by the consultant:

Toxics

Across all options, there are no significant differences in effluent concentrations for toxics.

Most toxics (such as benzene, toluene) were found at or below detection levels in refinery effluents for all options.

There are some toxic pollutants found in most effluents, but at low levels (levels near detection).

Non-Toxics

For some pollutants, U.S. EPA BPT/BAT limitations are still the most stringent (eg. TSS).

For other non-toxic pollutants, more stringent options may apply (eg. COD).

Flow

Flow reduction seems to be the most significant factor in reducing pollutant loadings in process wastewater.

Resulting from the above evaluations of technologies, the following remain as viable, demonstrated options for the discharge of wastewater from Ontario petroleum refineries:

Process Wastewater:	**Option 1** **Option 2A**
OTCW System Options:	**Option 1** **Option 2**
Cooling Tower System Options:	**Option 1** **Option 2**
Storm water Options:	**Option 1**

4.2 - PERFORMANCE OF BAT OPTIONS

The performance of the refineries can be described in terms of effluent quality (pollutant discharge concentrations) and the amount of wastewater discharged (effluent flow). The loading of pollutants discharged to the environment is calculated by multiplying effluent flow by effluent concentration.

4.2.1 - Effluent Concentrations

Final effluent concentration data for the possible BAT refineries identified within the United States and Canada were compared with the effluent concentration data obtained from the in-depth sampling and analysis program carried out under MISA for the seven Ontario refineries.

The availability of performance data for the Ontario refineries, Shell Montreal refinery (Canada - outside Ontario), and the seven U.S. refineries (the world), varies widely. Concentration data for four conventional parameters and one toxic parameter were obtained from the Environment Canada survey of Canadian refineries for the Shell Montreal refinery. Data obtained from U.S. EPA permit monitoring requirements for the seven best refineries in the U.S. included five conventional parameters and seven toxic parameters. In comparison, the MISA monitoring database contains information on 149 parameters of which 18 were confirmed, through the Quality Assurance/Quality Control (QA/QC) analysis[5], to be present at quantifiable levels.

Ontario Refineries vs. Canada - Outside Ontario

Out of the 22 Canadian refineries outside Canada, only Shell Montreal qualified as a possible BAT plant. A comparison between the performance of Shell Montreal in 1987[4] and the average values obtained at the seven Ontario refineries during December 1988 and November 1989 is presented in Table 4.5. It is evident from Table 4.5, that the average performance of the seven Ontario refineries during 1989 was markedly superior to that of Shell Montreal during 1987.

TABLE 4.5

COMPARISON BETWEEN PERFORMANCE OF SHELL MONTREAL (1987) AND AVERAGE OF SEVEN ONTARIO REFINERIES (1988-1989)

PARAMETER	Shell Montreal mg/l	Average of Seven Ontario Refineries mg/l
Oil and Grease	10.94	2.4
Total Suspended Solids	50.16	22.4
Phenolics (4AAP)	0.18	0.011
Sulfides	0.12	0.09
Ammonia	3.74	2.0
Acute Toxicity	Nil	Nil

From the analysis of refineries across Canada, the consultant concluded that there are no refineries outside of Ontario which have better performance than Ontario refineries.

Ontario Refineries vs. Seven Best in the U.S.

The average performance of the seven best refineries in the U.S. was compared to the average performance of the seven refineries within Ontario.

TABLE 4.6

COMPARISON OF PERFORMANCE FOR
THE 7 BEST U.S. REFINERIES VERSUS THE 7 ONTARIO REFINERIES
EFFLUENT CONCENTRATIONS

POLLUTANT (mg/l)	AVERAGE OF 7 ONTARIO REFINERIES	BEST ONTARIO REFINERY (NANTICOKE)	AVERAGE OF 7 BEST U.S. REFINERIES	BEST U.S. REFINERY
TSS	22.4	7.0	31	11
COD	49.2	30.6	85	58
Oil & Grease	2.4	1.8	4.08	1.79
Ammonia	2.0	0.34	5.21	0.10
Sulfide	0.09	0.004	< 0.03	< 0.03
Phenolics (4AAP)	0.011	0.004	0.047	0.004
Chromium (Total)	0.112	0.009	0.028	0.010
Lead	0.004	0.003	< 0.02	< 0.005
Zinc	0.290	0.027	0.09	< 0.005
Benzene	0.0007	0.0002	< 0.005	< 0.004
Toluene	0.0007	0.0002	< 0.005	0.004
Naphthalene	< 0.001	< 0.001	< 0.003	0.001
Copper	0.009	0.006	< 0.012	< 0.006
Nickel	0.010	0.006	< 0.08	0.036

NOTE: The data for the Ontario refineries shown in this table corresponds to the process effluent summaries attached in the Appendix A of this document. Data shown in the consultant's report may vary slightly due to the fact that the consultant was doing the BAT study in parallel with the validation and QA/QC analysis of the data.

Where there is a "<" sign followed by a number, it means that the compound was not detected at the present detection limit.

Presented in Table 4.6 are the average and the lowest (best) concentrations for the seven U.S. refineries and the average and the lowest (best) pollutant discharge concentrations for the seven Ontario refineries. For all refineries, most toxics were found at or below the detection level, including parameters which are characteristic of refinery effluents (benzene, toluene, etc).

Based on the above comparison, the consultant concluded that the performance of Ontario refinery wastewater treatment plants, in terms of effluent concentrations, is superior to that of their seven best U.S. counterparts.

4.2.2 - Effluent Flow

The volume of wastewater discharged from refineries, like pollutant discharge concentrations, is considered to be an indicator of a refinery's overall performance level. In order to evaluate the present level of water use within refineries, the consultant utilized the U.S. EPA's BPT flow model, developed as a part of the BPT Effluent Limitations[6].

In order to calculate the allowable amount of waste water per unit of throughput (USGAL/BBL) using the BPT flow model, the Ontario refineries were subcategorized using the system developed by the U.S. EPA. The U.S. EPA's system involved the classification of each refinery as one of five types: Topping (A), Cracking (B), Petrochemical (C), Lube Oils Processing (D), or Integrated (E). The placement of a refinery in a particular subcategory was dependant upon the types of processes employed. The seven Ontario refineries fell into three of the five subcategories; B, C, and D.

For each refinery, a size and process factor was calculated using the method outlined in the U.S. BPT Effluent Limitations and Guidelines and from information contained within the consultant's report on the current status of the refineries in Ontario. The final U.S. EPA BPT flow was calculated for each refinery by multiplying the respective subcategory median flows by the calculated size and process factors for each refinery.

Ontario Refineries vs Seven Best in the U.S.

The calculated BPT flows, actual flows, and the ratio of actual to calculated BPT flows for the seven Ontario refineries, is shown in Table 4.7. The actual flow data from the Ontario refineries were obtained from monitoring conducted under the MISA program. The corresponding information for the seven best U.S. refineries is contained in Table 4.8.

TABLE 4.7

ONTARIO REFINERIES
PROCESS WASTEWATER FLOWS

REFINERY	EPA SUBCATEGORY	FLOW (USGAL/BBL)		FLOW RATIO
		ACTUAL	U.S. EPA BPT	ACTUAL/BPT
Esso (Sarnia)	D	66	72	0.92
Shell (Sarnia)	C	54	27	2.00
Suncor (Sarnia)	C	34	32	1.06
Novacor (Corunna)	C	21	32	0.66
Petro Canada (Oakville)	B	19	28	0.68
Petro Canada (Mississauga)	D	69	58	1.19
Esso - Nanticoke	B	15	31	0.48
AVERAGE				1.0

TABLE 4.8

SEVEN BEST U.S. REFINERIES
PROCESS WASTEWATER FLOWS

REFINERY	EPA SUBCATEGORY	FLOW (USGAL/BBL)		FLOW RATIO
		ACTUAL	BPT FLOW	ACTUAL/BPT
Pacific (CA)	B	3.56	22.88	0.16
Chevron (CA)	E	27.64	86.96	0.32
Chevron (UT)	B	19.57	25.89	0.76
BP Oil (WA)	B	17.31	19.24	0.90
Ashland (OH)	B	14.71	30.94	0.48
Mobil (NJ)	D	122.31	34.85	3.51
Conoco (CO)	B	8.4	26.0	0.32
Average				0.92

As can be seen from Tables 4.7 the average flow ratio of the Ontario refining sector is 1.0, which means that the "Ontario BPT flow" is equivalent to the U.S. EPA BPT flow. Table 4.8 shows, however, that the average flow ratio of the seven best U.S. refineries is 0.92 or 92% of the calculated U.S. EPA BPT flow. The consultant concluded therefore, that effluent flow reductions within Ontario refineries may be possible and undertook a further study together with the Ministry.

In order to substantiate flow reductions below those calculated using the U.S. EPA's BPT flow model, the consultant obtained information from the second refining industry survey conducted by the U.S. EPA in 1976. The analysis of data from this survey, showed that, with the exception of the simplest refineries, plants in the U.S. were at or above their respective BPT model flows. Therefore, it was concluded that although flow reductions may be possible within the Ontario refining industry, the level to which refineries can reduce their water consumption cannot be ascertained at this time.

4.3 - THE SELECTED BAT OPTION

The BAT consultant concluded that, out of nine preliminary BAT options for process wastewater, only options 1 and 2A are demonstrated.

Both options 1 and 2A assume the same technology train and are based on the U.S. EPA flow model for developing the flow component of the loading limit. The performance values for the technology options are based on:

Option 1	Effluent concentrations used in the U.S. EPA Effluent Limitations for the Petroleum Refining Point Source Category.
Option 2A	Effluent concentration from the average performance of the seven Ontario refineries from the MISA monitoring database.

Since option 2A achieves better performance than option 1 with the same technology train, the BAT subcommittee selected option 2A to be used in setting limits for Ontario refineries.

Option 2A - Ontario BPT Flow

This option is based on a specified technology train, limited wastewater discharge derived from a statistical flow model and pollution prevention measures.

The technology train included in this option is as follows: sour water stripper, flow equalization (to reduce the effects of shock loads of flow, temperature and contaminant concentration on the treatment plant), initial oil and solids removal through the use of API or baffle plate separators, further oil and solids removal with clarifiers or DAF units, biological treatment with secondary clarification, polishing of the effluent using filtration or polishing pond, and the in-plant treatment of catalytic reformer scrubber wastewater with GAC.

The option includes the reduction of wastewater flow to the levels predicted by the U.S. EPA BPT flow model, achieved through additional source control (reuse, recycle). The U.S. EPA BPT flow model reflects the amount of wastewater generated from processes used to refine crude oil in well operated refineries. Three of the seven Ontario refineries are presently operating above their calculated BPT model flows. Thus, the use of the calculated BPT model flows as a basis for limits in Ontario would, as a minimum, bring the three refineries down to the current average flow of the Ontario refineries.

The pollution prevention measures include Chemical Additive Substitution (CAS) - replacement of zinc and chromium based additives in the recirculating cooling water systems with phosphate based additives.

4.4 - RECOMMENDED BAT OPTIONS

4.4.1 - The JTC Recommended Option

The BAT Subcommittee recommended to the JTC that option 2A be assessed for economic achievability.

The recommendation of the BAT Subcommittee was accepted.

SAIC recommended that detailed water-use studies be conducted at all Ontario refineries in order to identify areas where water use may be reduced.

4.4.2 - The Ministry Recommended Option

Option 2B was reviewed in more detail by the Ministry.

Option 2B is based on the same technology train, performance values and pollution prevention measures as specified in option 2A, but considers a lower effluent flow for establishing limits. It implies the reduction of waste water flow to 50% of the level predicted by the U.S. EPA BPT flow model and is representative of the flow achieved by the Nanticoke refinery. Using this flow and the concentrations of the seven Ontario refineries, results in loading limits which reflect a further reduction in the discharge of contaminants when compared to option 2A.

This option, which comes closer to achieving the MISA goal of virtual elimination, was favoured by the Ministry .

For this reason, the Ministry recommended that an economic assessment should also be conducted on option 2B[*].

Options 2A and 2B will henceforth be referred to as options A and B.

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[*] Option 2B was not recommended by the JTC since the conclusion of the BAT Subcommittee was that the 50% flow reduction could not be justified for old refineries. Older plants, that are mostly water-cooled, may have to dismantle and completely rebuild their existing cooling systems and/or production processes to achieve a 50% reduction in flow. For such plants, a complete rebuild would entail substantially greater capital costs than had been estimated by the consultant and would disrupt production activities with a potential reduction in production and reduced revenues.

4.5 - ECONOMIC ACHIEVABILITY (EA)

In order to develop effluent limits based on the BAT(EA), the Ministry conducted an economic assessment of BAT options identified for the petroleum refining sector. This assessment was done through the Joint Technical EA Subcommittee which included representatives from the Ministry, industry and Environment Canada.

The EA subcommittee was assigned a task of collecting the data necessary to conduct the economic impact assessment and developing necessary procedures, methodologies and assumptions for the assessment of options A and B.

4.5.1 - The Economic Assessment

The key steps followed in conducting an economic assessment are:

- derive least-cost abatement functions for each refinery with estimates of costs and contaminant removals for each BAT option recommended by the BAT subcommittee
- evaluate the cost effectiveness of selected BAT options at each refinery in terms of the cost per unit of pollutant removed and the incremental cost per unit of incremental pollutant removal
- determine the distribution of costs and contaminant reductions among plants and firms
- analyze the ability of industry to pass on the regulation-induced costs as increased product prices
- evaluate the effects of estimated regulation-induced costs on the financial position of each firm or plant in the sector
- determine the effects of the regulation-induced costs on the competitive position of Ontario refineries

The results of the economic assessment are derived from an in-depth analysis of abatement options, their costs and the potential economic and financial effects associated with these costs. The details of the economic assessment are given in the economic assessment report for the petroleum refining sector[7].

Cost-effectiveness of Options

Contaminant removal by BAT option and cost estimates provided by the BAT consultant were used to derive least-cost abatement functions that show annualized costs of attaining related levels of final loadings at each refinery. Contaminant removal, in this case, represents the incremental reduction of loadings with the BAT option in comparison with the current (1989 MISA data) loadings.

The cost per unit of pollutant removed was calculated for each BAT option and used to compare the cost-effectiveness of options.

Both options A and B assume the implementation of a pollution prevention technique - CAS - to reduce zinc and chromium loadings.

Option A - contaminants removal:

Toxic contaminants - 71%
Conventional contaminants - 26%

Estimated cost of option A:

Capital cost	$ 57.5 million
Operating cost	$ 8.6 million
Annualized cost (over 10 years)	$ 11.2 million

Option B - contaminants removal:

Toxic contaminants - 80%
Conventional contaminants - 39%

Estimated cost of option B:

Capital cost	$ 96.4 million
Operating cost	$ 13.3 million
Annualized cost (over 10 years)	$ 18.2 million

When the cost-effectiveness analysis was performed on the two options the results showed that option B was not a cost-effective option. Compared to option A, option B could result in a 13% incremental reduction in loading of conventionals and 9% incremental reduction in loading of toxic contaminants for an additional expenditure of $38.9 million in capital cost.

CAS alone, which is part of both options, results in 68% reduction of toxic contaminants loading at an estimated cost of $1.0 million.

The results of the cost-effectiveness analysis indicate that option A - Ontario BPT flow option, is a more cost-effective option.

4.5.2 - Financial Impact Assessment

The petroleum refining sector in Ontario consists of seven plants - refineries, owned by five companies. These five companies own plants outside of Ontario also. The financial impact of the regulation would be better assessed if it could be based on plant information, however, the Ontario petroleum refining sector did not provide plant level financial information. Therefore, the financial impact assessment was conducted on a firm level and not on a plant level.

Option A:

Ontario refineries may have to spend up to $57.5 million in capital and $8.6 million in annual operating expenditures to comply with option A. These expenses amount to $11.2 million on a before tax annualized basis over a 10 year period, assuming that all the firms are profitable. Based on a comparison of current contaminant loadings (1989 MISA data) against proposed limits, it appears that three refineries would not have to incur additional abatement costs to be in compliance with this regulatory option. If the three refineries could maintain the 1989 level of performance, the above estimated capital cost for the sector may be lower. The remaining four refineries would have to reduce their contaminants loading by improving the effluent quality and/or reducing the flow of effluent discharged.

Financial impact assessments show that the costs associated with this option would have small effects on financial performance indicators for the sector. The percentage change in each of the financial indices (capital employed, debt to total assets) is less than 1%. The poor financial performance of the petroleum companies in 1991 would be slightly worsened if the costs were incurred in that year.

Option B:

Ontario refineries may have to spend up to $96.4 million in capital and $13.3 million in annual operating expenditures to comply with option B. These expenses amount to $18.2 million on a before tax annualized basis over a 10 year period, assuming that all the firms are profitable. Based on a comparison of current contaminant loadings against proposed limits, it appears that two refineries may not have to incur additional abatement costs to be in compliance with this regulatory option. The remaining five refineries would have to reduce their contaminants loading by improving the effluent quality and/or reducing the flow of effluent discharged. (e.g. one of the refineries would have to reduce the present flow by 70%).

Financial impact assessments show that the costs associated with this option (as estimated by the BAT consultant) would not have significant effects on financial performance of the sector. The percentage change in each of the financial indices assessed (eg. capital employed, debt to total assets) remains at less than 1%. The poor financial performance of the petroleum companies in 1991 would be further worsened if the costs were incurred in that year. These effects may be understated if the actual retrofitting costs are underestimated, as is believed by industry.

After reviewing the cost effectiveness analysis, the financial impact assessment, and giving recognition to uncertainty of the costs of option B and the concern of whether the flow levels required by option B are technically achievable, the Ministry determined that option A represented the "economically achievable" option.

4.6 - REFERENCES

1. Ontario Ministry of the Environment. MISA White Paper. Water Resources Branch, Toronto, Ontario. June 1986.

2. Ontario Ministry of the Environment. MISA Issues Resolution Process - Issue Resolution Committee Reports. Toronto, Ontario, June 1990.

3. Science Applications International Corporation. Best Available Technology For The Ontario Petroleum Refining Sector. The Ontario Ministry of the Environment, July 1992.

4. Environment Canada. Environmental Status Report for the Canadian Petroleum Refining Industry 1987. Report EPS 1/PN/3. Ottawa, Ontario. July 1990.

5. Ontario Ministry of the Environment. Report on the Analysis of the Quality Assurance and Quality Control Data for the Petroleum Refining Sector. Toronto, Ontario. July 1992.

6. The United States Environmental Protection Agency (1982). Development Document for Effluent Limitations Guidelines New Source Performance Standards and Pretreatment Standards for the Petroleum Refining Point Source Category. Effluent Guidelines Division - Office of Water Regulations and Standards. Washington D.C. 1982.

7. Ontario Ministry of the Environment. MISA Economic Assessment - Potential Water Pollution Abatement Programs for Ontario Petroleum Refineries. Toronto, Ontario 1992.

CHAPTER 5

THE EFFLUENT LIMITS

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5.0 - THE EFFLUENT LIMITS

Limits for Ontario refineries were developed by the JTC Limits Setting Subcommittee (LSS) with input from the JTC Monitoring Data Evaluation Subcommittee (MDES). The statistical procedures for the limits setting process as outlined in the IRC[1] report were followed.

The LSS had the following tasks:

- to identify the types of effluent streams to be limited
- to define the type of limits (concentration, loading, daily, monthly, production based)
- to produce a list of parameters to be limited
- to derive numerical limits based on selected Best Available Technology (BAT)

The Types of Effluents to be Limited

Under the MISA Effluent Monitoring Regulation for the petroleum refining sector, the following types of streams were monitored at various frequencies and for various parameters: process effluent, once-through cooling water effluent, storm water effluent, landfarm leachate effluent and emergency overflow effluent.

Under the MISA effluent limits regulation, discharge limits will be imposed on the process effluent since this effluent contributes most of the contaminant loadings. The storm water effluent in the Ontario refineries is contained in ponds and discharges are controlled. The storm water can be treated in the biotreater together with the process effluent. Three of the seven refineries treat all of their storm water with the process effluent on a regular basis.

Once-through cooling water effluent will not be limited but will be monitored for assessment. The assessment data can be used if necessary, to develop suitable control programs for ensuring that cooling water is contaminant free.

The Form/Type of Effluent Limits

Effluent limits can be expressed as loading limits, production based loading limits or concentration limits. They can be set on a daily or monthly average basis.

Effluent limits for the petroleum refining sector developed under the MISA program are expressed as pollutant loadings, i.e. the mass of the pollutant discharged in the effluent. They comprise two main components: concentration and effluent flow. Effluent flow is dependent on production processes and production rate.

The LSS adopted the approach of production based loading limits for the petroleum refining sector.

The List of Parameters to be Limited

The list of parameters that are considered for effluent limits consists of those parameters that can be controlled by the defined BAT. Under special circumstances, parameters like 2,3,7,8-TCDD (tetrachlorodibenzo-p-dioxin) and 2,3,7,8-TCDF (tetrachlorodibenzofuran) which pose a significant threat to human health and the environment, are also limited regardless of BAT.

The IRC report states that limits should be set on a short list of easy-to-measure toxic and conventional parameters. This statement is based on the assumption that compliance with the requirements of the short list will correlate with the control of a longer list of contaminants of concern. For the petroleum refining sector, effluent limits have been developed for eleven parameters including the two "special parameters": 2,3,7,8-TCDD and 2,3,7,8-TCDF.

The Derivation of Numerical Limits

BAT plant identification and performance data are fundamental to developing the effluent limits. Performance data from BAT, as described in chapter four, was applied to the parameters selected for limits. The long term average (LTA) concentrations and variability factors were calculated in agreement with the recommendation given in the IRC report. The flow of wastewater per unit of production defined by BAT is used in loading calculations. The production based loading limits are expressed in kilograms of contaminants discharged per day.

5.1 - LIST OF PARAMETERS FOR LIMITS

The list of parameters for limits was developed following general steps:

- preliminary selection of candidate parameters from the sector monitoring database
- QA/QC assessment of the candidate parameters
- assessment of candidate parameters for possible surrogates
- assessment of BAT for the QA/QC validated candidate parameters
- assessment of "special" parameters to be added to the list of candidate parameters

5.1.1 - Preliminary Selection of Candidate Parameters*

In order to select the parameters for limits, a selection criterion based on the 90/10 rule was applied to the 1989 MISA monitoring data. Parameters were deleted from further consideration if the effluent monitoring data showed (at a 95% confidence level) that 90% of the data were at concentrations less than the Regulation Method Detection Limit (RMDL).

The preliminary selection of parameters through application of the above rule to each refinery produced a list of 34 parameters in total as the preliminary candidates for limits. Table 5.1 shows the 34 parameters as well as the refineries for which they would be selected as candidates for limits.

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* The preliminary selection of candidate parameters was conducted before the final recommendation on the selection of parameters was published in the IRC Final Report Summary (1991), however, the list did not change, when checked against a new recommendation.

TABLE 5.1

PRELIMINARY SELECTION OF PARAMETERS

ATG	Parameter	Esso Sarnia	Petro-Canada Mississauga	Petro-Canada Oakville	Nova Corunna	Shell Canada Sarnia	Suncor Inc. Sarnia	Esso Nanticoke
1	COD	X	X	X	X	X	X	X
2	Cyanide Total	X	X	X	X	X	X	X
3	Hydrogen ion (pH)	X	X	X	X	X	X	X
4a	Ammonia plus Ammonium	X	X	X	X	X	X	X
	Total Kjeldahl nitrogen	X	X	X	X	X		X
4b	Nitrate+Nitrite	X	X	X	X		X	X
5a	DOC	X	X	X	X	X	X	X
5b	TOC	X	X	X	X	X	X	X
6	Total phosphorus	X	X	X	X	X	X	X
7	Specific conductance	X	X	X	X	X	X	X
8	Total suspended solids	X	X	X	X	X	X	X
	VSS	X	X	X	X	X		
9	Aluminum	X	X	X	X	X	X	X
	Chromium		X	X	X	X		
	Copper						X	
	Molybdenum			X				X
	Vanadium		X					
	Zinc	X	X	X	X	X	X	X
10	Arsenic	X	X	X	X		X	X
	Selenium	X		X				X
11	Chromium (hexavalent)	.	.	.	.	.	.	X
12	Mercury		X					X
14	Phenolics (4AAP)	X	X	X	X	X	X	X
15	Sulphide	X	X	X	X	X	X	X
16	1,2-Dichloroethane		X	X				X
	1,2-Dichloropropane			X				
	Chloroform		X		X		X	X
	Chloromethane			X				
	Methylene chloride							X
17	Benzene	X						
	Toluene	X				X		
	m-Xylene and p-Xylene	X						
	o-Xylene	X		X				
25	Oil and grease	X	X	X	X	X	X	X

Note:

X	Indicates parameter selected and the corresponding refinery
.	Not monitored by that refinery
ATG	Analytical Test Group

5.1.2 - QA/QC Assessment of Monitoring Data

Each parameter from the candidate list was assessed by applying the QA/QC procedure as established in the IRC process. The validity of analytical results was assessed through analysis of blanks, travelling blanks, travelling spiked blanks and duplicate sample analytical results. Details of the QA/QC analysis of the monitoring database are described in the QA/QC report entitled "The Report on the Analysis of the Quality Assurance and Quality Control Data for the Petroleum Refining Sector"[2].

Of the 34 parameters originally selected, eighteen were found to be present in process effluents discharges from all, or almost all, of the Ontario petroleum refineries. The eighteen parameters, categorized as "frequent occurrence", are mainly conventional and non-conventional contaminants, and include: chemical oxygen demand (COD), cyanide, pH, ammonia plus ammonium, total Kjeldahl nitrogen (TKN), nitrate plus nitrite, dissolved organic carbon (DOC), total organic carbon (TOC), total phosphorus, specific conductance, total suspended solids (TSS), volatile suspended solids (VSS), aluminum, zinc, arsenic, phenolics (4AAP), sulphide, and oil and grease. The QA/QC assessment of these parameters confirmed their presence at such levels that they could be used to set quantitative and statistically valid limits.

The remaining 16 preliminary candidates, which were categorized as "infrequent occurrence", were found at very low levels and near the detection limit. These parameters included some metals and trace organics. The QA/QC assessment showed that the presence of these parameters at such low levels cannot be confirmed. These data cannot be used to set statistically valid quantitative limits. The following parameters were eliminated from the preliminary candidate list for the following reasons:

- Methylene chloride - its presence was the result of laboratory contamination
- 1,2-Dichloroethane and chloroform - due to insufficient data
- Chromium - high variability of data
- Molybdenum, selenium and mercury - data at very low levels
- Toluene and o-xylene - suspected of both field and laboratory contamination
- Copper, vanadium, 1,2-dichloropropane, chloromethane, benzene, chromium (hexavalent) and m- & p-xylene - as "unique" parameters, i.e. found in one location only, very infrequently and at low concentrations (close to RMDL)

The list of candidate parameters is shown in Table 5.2.

TABLE 5.2

LIST OF CANDIDATE PARAMETERS

PARAMETER
COD
Cyanide total
Hydrogen ion (pH)
Ammonia plus ammonium
Total Kjeldahl nitrogen
Nitrate + nitrite
DOC
TOC
Total phosphorus
Specific conductance
TSS
VSS
Aluminum
Zinc
Arsenic
Phenolics (4AAP)
Sulphide
Oil and grease

The QA/QC evaluation of "non-candidate" parameters confirmed their absence at the reported method detection limits.

5.1.3 - Assessment for Possible Surrogates

The list of 18 candidate parameters was reviewed in detail to establish:

- what each parameter measures
- how relevant and critical it is to have a limit for a particular parameter
- can the parameter be controlled successfully - i.e. whether BAT performance data support the limit

In addition to the above consideration a search was made for possible surrogate parameters. Although statistical correlations for surrogate parameters were not established, based on the Best Professional Judgement (BPJ) of the MDES and LSS, the following facts were considered and subsequent decisions made:

Nitrogen Compounds

TKN (total Kjeldahl nitrogen), ammonia plus ammonium and nitrate + nitrite all represent some measure of nitrogen:

- TKN is a measure of both organic nitrogen and total ammonia.

- Ammonia plus ammonium is a measure of ionized and un-ionized ammonia (un-ionized ammonia is toxic to fish).
- Nitrate + nitrite is a measure of total oxidized nitrogen.

Ammonia plus ammonium was chosen as a parameter for limits for the following reasons:

- known impact on environment (toxicity to fish)
- best represents nitrogen pollutants generated in the petroleum refining processes
- can be treated - treatment for ammonia is a part of the defined BAT and the impact of ammonia on the environment is known
- a parameter regulated under the federal regulations

Reasons for not choosing TKN and nitrate + nitrite are:

- Since organic nitrogen compounds were not detected during monitoring and these would be also reflected in TKN together with total ammonia, there is no need to set the limit on TKN if ammonia is limited.
- Nitrate + nitrite measuring nitrification in the biological treatment. Nitrification does not normally occur in biological treatment at a refinery since ammonia (i.e. nitrogen source) has been removed upstream of the treatment system.
- BAT treatment for nitrate + nitrite was not established

COD, TOC and DOC

COD (chemical oxygen demand), DOC (dissolved organic carbon) and TOC (total organic carbon) represent a global measure of the level of organic contamination.

- COD measures both organic and inorganic substances (for example sulphide and ammonia). The RMDL for COD is relatively high - 10 mg/L.
- DOC measures water soluble portion of organic carbon. The RMDL for DOC is relatively low - 0.5 mg/L.
- TOC measures both particulate and dissolved carbon. The RMDL is relatively high - 10 mg/L.

DOC was chosen as the parameter for limits for the following reasons:

- much lower detection than COD and TOC
- more likely to reflect trace contaminants in refinery effluents than TOC and COD
- particulate organic carbon will be captured in VSS (TSS)
- inorganic substances that would be reflected in COD will be captured by ammonia and sulphide

5.1.4 - Assessment of BAT

Each candidate parameter was assessed against the selected BAT.

This assessment resulted in a further reduction of the candidate parameter list. The LSS concluded that the performance data of the Ontario refineries for the following parameters could not be proven to be the result of the BAT treatment: cyanide, aluminum, arsenic, phosphorus, zinc and specific conductance.

5.1.5 - Assessment of Special Parameters

The following parameters were not selected by the selection process but they were considered for limits because they pose a threat to human health and the environment.

- Dioxins and furans 2,3,7,8 TCDD was identified by the International Joint Committee (IJC) as a critical substance and defined as a bioaccumulative persistent toxic substance. Dioxins and furans were not detected in the refinery effluents, but due to potential generation of these compounds during reformer catalyst regeneration, the LSS recommended the following limit:

  the sum of dioxins and furans expressed in toxic equivalents (TEQ) of 2,3,7,8 TCDD should be "non detect" in the refinery effluents.

After reviewing the recommendation of the LSS, the Ministry is proposing a "non-measurable" limit for 2,3,7,8 TCDD and 2,3,7,8 TCDF.

In April 1992 the Ministry issued a candidate substance list for bans and phase outs which included 2,3,7,8 TCDD[3].

- Mercury has been identified by the IJC as a critical substance and is defined as a bioaccumulative persistent toxic substance. During the year of monitoring, mercury was detected in one refinery only and at a very low level. In the past, the refinery had used some instruments which contained mercury and the speculation was that the trace mercury concentration came from some dismantled instrument. Mercury is not used or produced by refineries and BAT treatment was not identified. It is known, however, that mercury is still detected in the sediments of the St. Clair river probably as a result of the discharges from the chemical industry in the past.

The LSS did not place mercury on the candidate parameter list for limits.

Mercury is also proposed as a candidate substance for bans and phaseouts and will be covered by other components of the MISA program.

- Zinc and Chromium During the year of monitoring in the petroleum refining sector, the effluent of one refinery was toxic to fish on a few occasions due to the presence of zinc and chromium. The source of zinc and chromium was cooling tower blowdown. Zinc and chromium compounds were used as anti-corrosion additives in the cooling tower systems in four of the seven refineries. One out of four refineries replaced zinc-chromium additives with phosphate based chemicals in 1989 during the MISA monitoring.

  The LSS considered setting limits for zinc and chromium[**] using monitoring data of the three refineries which did not use zinc and chromium during 1989 monitoring. An analysis of available data, however, showed that chromium was not detected in those refineries. Zinc was detected in those refineries at different and highly variable levels. The conclusion of the subcommittee was that more information was needed to identify the sources of zinc and to establish a statistically valid database. The subcommittee did not place zinc or chromium on a candidate parameter list for limits.

Chemical additives substitution (CAS), specifically the replacement of zinc and chromium additives in cooling tower recirculating water, was identified by the BAT consultant as a pollution prevention measure. The LSS agreed that all the refineries should stop using zinc and chromium additives and replace them with phosphate based chemicals. Industry was an active participant in this agreement. The remaining three refineries which still used zinc and chromium additives at the time of these deliberations, have since replaced them with phosphate based additives, on a voluntary basis. By the end of 1991, the use of zinc and chromium was discontinued in all Ontario refineries.

- Phosphorus Since zinc and chromium were going to be replaced with phosphate based chemicals, the LSS considered setting limits for phosphorus. However, the industry was concerned that the 1989 MISA monitoring data did not truly reflect the new mode of operation, and that limits could be underestimated if they were developed on the basis of the MISA monitoring data. The subcommittee agreed that more monitoring will be needed after the implementation of CAS before limits can be set. The subcommittee did not place phosphorus on a candidate parameter list for limits.

[**] Chromium was selected as a candidate parameter but it was subsequently eliminated through the QA/QC assessment.

After reviewing the limited parameters list as proposed by the JTC, the Ministry was concerned about the absence of a limit for phosphorus since the objective of the Great Lakes Water Quality Agreement (GLWQA) is that the level of phosphorus inputs should be controlled as much as possible.

The Ministry assessed all the available information on phosphorus monitoring after the implementation of CAS in two refineries and is proposing a loading limit for phosphorus which is based on data from the two refineries. Coincidentally, the monthly average concentration of 1 mg/l for the two refineries is identical to the GLWQA objective for phosphorus for municipal waste treatment facilities.

- BTX (Benzene, Toluene, Xylenes) Although not selected by the process as candidate parameters, BTX compounds were considered for limits. Benzene and toluene were identified by the American Petroleum Institute (API) and the U.S. Environmental Protection Agency (EPA) as trace hazardous contaminants in refinery effluents. Monitoring data from the Ontario refineries, however, show an LTA concentration for benzene equal to the RMDL. At this level, it is not possible to develop defensible limits.

Since BTX compounds are treated successfully by biological treatment, the conclusion of the BAT subcommittee and LSS was that by controlling conventional parameters, BTX will be controlled also. The subcommittee did not place BTX compounds on a candidate parameter list.

Table 5.3 represents a final list of candidate parameters for limits.

TABLE 5.3

FINAL LIST OF CANDIDATE PARAMETERS FOR LIMITS

ATG	PARAMETER
3	Hydrogen ion (pH)
4a	Ammonia plus Ammonium
5a	DOC
6	Total Phosphorus
8	TSS
	VSS
14	Phenolics (4AAP)
15	Sulphide
24	2,3,7,8 TCDD
	2,3,7,8 TCDF
25	Oil and grease

5.2 - THE DEVELOPMENT OF EFFLUENT LIMITS

Effluent limits for the petroleum refining sector developed under the MISA program are expressed as pollutant loadings; i.e. the mass of the pollutant discharged in the effluent. They comprise two main components: concentration and effluent flow.

In chapter 4, the Ontario petroleum refining sector BAT(EA) was defined as option A, which implies that the limits will be based on the "Ontario BPT flow"* and the average concentration performance of the Ontario refineries.

5.2.1 - Effluent Flow

From the analyses conducted by the consultant and through the work of the MISA JTC subcommittees, the U.S. EPA BPT flow model (developed by the U.S. EPA under their Best Practicable Control Technology Currently Available Effluent Guidelines and Limitations) was adopted as a flow basis for limits in Ontario. A discussion of the development of the BPT flow model by the U.S. EPA is presented below, followed by the rationale and calculation of BPT flow for the Ontario refineries.

The U.S. EPA's Flow Models

The first U.S. EPA study (1972) consisted of a survey of over 250 refineries located across the country. The survey requested detailed information on all aspects of refinery operations: manufacturing processes, products, water use, wastewater sources, treatment systems, and type of cooling. From this information, the U.S. EPA identified over 150 distinct processes utilized within the industry and established that the amount of wastewater produced in refineries is significantly dependant upon the processes used.

In order to address the diversity of the refining industry and develop a representative basis for flow limitations, the U.S. EPA subcategorized refineries by the types of processes employed. The collection of processes in each of the 5 subcategories (see Table 5.4) reflected those processes which generate significant amounts of wastewater. Multiple regression analyses were performed on data in each subcategory to correlate achievable process effluent flow to process variables. In order to ensure that the flow model would reflect the water usage by processes and not cooling, data from 94 out of 250 refineries were utilized in these analyses. The 94 refineries were selected on the basis of the minimum use of Once Through Cooling Water (OTCW) for their cooling needs. The selection criterion was that less than 3% of cooling needs are achieved with OTCW. The rest of the cooling was done by air cooling or by cooling towers.

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* "Ontario BPT flow" is calculated for each Ontario refinery using the U.S. EPA flow model and Ontario flow allowances.

TABLE 5.4

SUBCATEGORIZATION OF THE PETROLEUM REFINING INDUSTRY

SUBCATEGORY	MEDIAN FLOW USGAL/BBL	BASIC REFINERY OPERATIONS INCLUDED
Topping (A)	20	Topping and catalytic reforming whether or not the facility includes any other process in addition to topping and catalytic process. This subcategory is not applicable to facilities which include thermal processes (coking, visbreaking, etc.) or catalytic cracking.
Cracking (B)	25[A]	Topping and cracking, whether or not the facility includes any processes in addition to topping and cracking, unless specified in one of the subcategories listed below.
Petrochemical (C)	30	Topping, cracking and petrochemical operations, whether or not the facility includes any process in addition to topping, cracking and petrochemical operations[B], except lube oil manufacturing operations.
Lube (D)	45	Topping, cracking and lube oil manufacturing processes, whether or not the facility includes any process in addition to topping, cracking and lube oil manufacturing processes, except petrochemical operations[B].
Integrated (E)	48	Topping, cracking, lube oil manufacturing processes, and petrochemical operations, whether or not the facility includes any processes in addition to topping, cracking, lube oil manufacturing processes and petrochemical operations[B].

[A] New Source Performance Standards (NSPS)
Flow for Subcategory B (cracking) is 14 USGAL/BBL (barrel of crude oil throughput)

[B] The term "petrochemical operations" shall mean the production of second generation petrochemicals (i.e., alcohols, ketones, cumene, styrene, etc.) or first generation petrochemical and isomerization products (i.e., BTX, olefins, cyclohexane, etc.) when 15% or more of refinery production is as first generation petrochemicals and isomerization products.

The five regression curves represented the best fit of flow (USGAL/day) versus production (BBL/day) for those refineries in each subcategory. In each case the median flow, representative of a refinery of average size and complexity, was chosen as the basis for flow limitations. Discrete factors, however, were required to account for size and complexity variations within a subcategory. The final flow model, with accompanying concentrations, became the basis for the EPA's BPT Effluent Limitations which were promulgated in 1974.

In 1976, the U.S. EPA conducted another survey of the petroleum refining industry. The data collected indicated that many refineries were making substantial improvements to their wastewater management systems. From these data, the EPA developed an alternate modelling approach to represent the industry flow of 1976.

In December 1979, the U.S. EPA published the flow model as part of the proposed BAT Effluent Limitations Guidelines. Numerous comments were received from both the public and the industry. Industry made significant comments on the technical accuracy and statistical validity of the flow model. In response, the EPA refined the flow model to consider those factors.

The U.S. EPA's treatment technology models for BPT and BAT limitations guidelines are identical. The U.S. EPA's studies of U.S. petroleum refineries demonstrated to its satisfaction that the existing BPT trains effectively removed the toxic pollutants found in the refinery wastewaters.

The difference between the BPT and BAT limits promulgated by the U.S. EPA was in the wastewater flow basis of the two sets of guidelines.

Before finalizing the BAT limits, the U.S. EPA conducted a cost evaluation on a number of options and concluded that the costs associated with going beyond the BPT regulations was not justified. Thus, in October of 1982, the BAT Effluent Guidelines were promulgated as equal to the BPT Effluent Guidelines.

On January 27, 1983, the National Resources Defence Council (NRDC), filed suit against the EPA alleging that the EPA had erred in promulgating the BAT effluent limitations guidelines as equal to the BPT limitations.

The API and seven petroleum companies participated in these deliberations. As a result of negotiations to settle the suit, an agreement was established which regulated three pollutants; phenolics, hexavalent chromium, and total chromium, to the more stringent levels of BAT treatment. All other pollutants regulated under the BPT effluent limitations guidelines remained unchanged. The revised BAT and BPT effluent limitations guidelines were promulgated by the U.S. EPA in 1985 and are still in effect.

Ontario BPT Flow

In order to "model" wastewater flows generated by Ontario refineries, the U.S. EPA method of grouping the refineries with common processes and products into "subcategories"[4,5] was used. Associated with each subcategory is a "median" process wastewater flow (USGAL/BBL) which is characteristic of a refinery of average size and complexity (see Table 5.4).

From information contained within the BAT consultant's Part II - "Report on the Status of Waste Water Generation and Treatment in Ontario Refineries"[7], each refinery in Ontario was subcategorized following the U.S. EPA's criteria. The seven Ontario refineries fell into three of the five EPA "subcategories":

Cracking (B)	Petro-Canada (Oakville Plant)
	Esso Petroleum (Nanticoke)
Petrochemical (C)	Shell Canada (Sarnia)
	Suncor (Sarnia)
	Novacor (Corunna)
Lube Oil Processing (D)	Esso Petroleum (Sarnia)
	Petro-Canada (Mississauga Plant)

To calculate the BPT flow limitations, the size and process factors associated with each refinery were required in order to adjust the subcategory median flow to reflect the characteristics of each refinery. The method used to calculate the size and process factors is outlined under the U.S. EPA's 40 CFR 419 regulation.

The final BPT process flow was calculated as the product of the subcategory median flow (refer to Table 5.4), the calculated size factor, and the calculated process factor. In the footnote "A" of Table 5.4, the median flow for the EPA's New Source Performance Standard (NSPS) is shown. The NSPS flow was applied to the Esso Petroleum (Nanticoke) refinery only, because of its "new" refinery classification under Canadian Federal and U.S. EPA Regulations. The EPA's NSPS limitations were promulgated along with the BPT limitations to account for refineries or processes built after 1974. The EPA had demonstrated that post 1974 refineries or processes could meet flows, depending upon the subcategory classification, 25 to 50% below that of the calculated BPT flows. Novacor (Corunna) is also considered a new refinery under Canadian Federal and the U.S. EPA Regulations, however, Novacor was not considered for NSPS flow due to its unique operation. Novacor, although classified as a "C" or "Petrochemical" refinery under the U.S. EPA subcategorization method, is not a "true" petrochemical plant. Novacor does not contain the typical topping and cracking processes utilized in the "C" category refineries and it produces petrochemical feedstocks, not final petrochemical products. Thus, it was concluded that Novacor's operation would be better represented using the BPT (rather than NSPS) flow model.

An example of the BPT process flow calculation for a 120,000 BBL/day "lube oil processing" (subcategory D) refinery is shown here. The calculated size factors, process factors, and BPT model flows for the seven Ontario refineries are presented in Table 5.5.

EXAMPLE

BPT FLOW CALCULATION FOR A
120,000 BBL/DAY, LUBE OIL PROCESSING (SUBCATEGORY D) REFINERY

Reported Crude Capacity (Crude Rate) = ***19 078 m^3/day*** = 120,000 BBL/day

From the Size Factor Table under Subcategory D (Lube) of the BPT Effluent Limitations[6], the reported crude capacity corresponds to a ***Size Factor = 0.88***

	UNIT THROUGHPUT (m^3/day)	CRUDE RATE (m^3/day)	UNIT THROUGHPUT / CRUDE RATE	WEIGHTING FACTOR	WEIGHTED FRACTION
CRUDE PROCESSES:					
ATMOSPHERIC DISTILLATION	19078	19078	1.00		
VACUUM DISTILLATION	4808	19078	0.252		
DESALTING	19078	19078	1.00		
TOTAL			2.252	1	2.252
CRACKING & COKING PROCESSES:					
FLUID CATALYTIC CRACKING	4483	19078	0.235		
HYDROCRACKING	1755	19078	0.092		
FLUID COKING	3568	19078	0.187		
HYDROTREATING	10836	19078	0.568		
TOTAL			1.082	6	6.49
LUBE OIL PROCESSES:					
PHENOL EXTRACTION	1812	19078	0.095		
KETONE DEWAXING	973	19078	0.051		
LUBE HYDROFINING	782	19078	0.041		
LUBE VACUUM TOWER	95	19078	0.005		
TOTAL			0.192	13	2.5
SUM OF WEIGHTED FRACTIONS					11.51

From the Process Factor Table under Subcategory D (Lube) of the BPT Effluent Limitations[4], the calculated sum of weighted fractions corresponds to a ***Process Factor = 1.98.***

Therefore, the ***BPT flow*** = Subcategory Median Flow x Size Factor x Process Factor
= 45 x 0.88 x 1.98
= ***78.4 USGAL/BBL***

NOTE: Asphalt Processes do not apply in this case.

$$\boxed{\text{WEIGHTED FRACTION} = \text{WEIGHTING FACTOR} \times \frac{\text{UNIT THROUGHPUT}}{\text{CRUDE RATE}}}$$

TABLE 5.5

CALCULATED U.S. EPA BPT MODEL FLOWS (USGAL/BBL) FOR THE SEVEN ONTARIO REFINERIES

Refinery Name	U.S. EPA Subcategory	Size Factor (1989 Data)	Process Factor (1989 Data)	Sub-Category Median Flow (USGAL/BBL)	Model Flow (USGAL/BBL)
Novacor (Corunna)	C	0.76	1.39	30	32
Suncor (Sarnia)	C	0.83	1.28	30	32
Shell Canada (Sarnia)	C	0.83	1.08	30	27
Petro Canada (Oakville)	B	1.04	1.09	25	28
Esso (Nanticoke)	B	1.23	1.00	14*	17
Esso (Sarnia)	D	0.88	1.82	45	72
Petro Canada (Mississauga)	D	0.71	1.82	45	58

Note: Size and process factors based on Ontario 1989 throughput

* U.S. EPA NSPS (New Source Performance Standard) Flow Limit.

Flow Allowances for Ontario Refineries

During the year long monitoring (December 1988 - December 1989) of petroleum refineries effluent discharges under MISA, the daily flow of wastewater discharged from Ontario refineries was measured. The measured flow included treated process water, and in some cases, ballast water, storm water, and wastewater emanating from sources not associated with the refinery (such as a chemical plant or research facility). The U.S. EPA BPT flow model, however, reflects a refinery process wastewater flow only. In the U.S., the permit writer assigns allowances on a site specific basis depending on the amount of non-process water treated.

In order to develop Ontario flow limits, methods were required to account for the additional flow from various non-process sources in addition to a "model" flow which only reflects the refinery process water.

Based on the analysis of the available information on wastewater flow from Ontario refineries, the volume of non-process wastewater was estimated in the following manner:

Ballast Water	The number of ships and quantity of ballast water treated during the year of monitoring was obtained from the refineries as a part of the consultant's questionnaire[7].

Non-Refinery Specific Processes	The volume of wastewater which did not originate from crude oil refining, but was treated in the refinery's treatment plant, was obtained from the plant records.
Storm water	The volume of storm water treated is different in each refinery due to different storm water handling practices. The volume of storm water treated in each refinery was estimated by the Ministry using site specific information obtained from each refinery. The areas of the refinery in which precipitation run-off is collected and treated were identified. The type of soil conditions at each site were also identified. The information obtained for each refinery was verified by plant representatives. The average precipitation data over the last 5 years in each region where the refineries are located were obtained from Environment Canada.

Utilizing the above information and the U.S. Soil Conservation Service (SCS) Unit Hydrograph Method, the total volume of storm water treated at each refinery was estimated on an annual basis. The SCS Unit Hydrograph method was utilized to convert the amount of precipitation (in inches or cm) to an equivalent amount of run-off (in inches or cm) which is dependant upon the soil conditions in the area (different permeability factor). The final amount of storm water treated in each plant was estimated using the following formula:

$$\begin{aligned} &\textbf{TOTAL STORM WATER TREATED} \\ &\textbf{IN REFINERY (m}^3\textbf{/year)} = \{\text{area } 1(\text{m}^2) * \text{run-off[from area 1](m/year)}\} \\ &\qquad + \{\text{area } 2(\text{m}^2) * \text{run-off[from area 2](m/year)}\} \\ &\qquad + \ldots + \{\text{area } n(\text{m}^2) * \text{run-off[from area n](m/year)}\}; \end{aligned}$$

where n is the number of areas from which storm water is treated.

Table 5.6 shows developed and undeveloped areas in refineries from which storm water is treated. Developed and undeveloped areas may have different type of permeability factors. Total area represents total area from which storm water is treated, not the total area of refinery property. Flow of storm water represents calculated annual run-off of storm water which is treated in each refinery in cubic metres. Flow in IGPM is also given in brackets since IGPM are more frequently used units by refineries.

$$\text{Flow "allowance"} = \frac{\text{Total storm water treated per year (USGAL/yr)}}{365 \text{ x Crude Processing Rate (BBL/day)}}$$

The flow "allowances" were calculated by dividing estimated annual flow by 365 days and the daily crude processing rate. To arrive at the final flow limitation for each Ontario refinery (USGAL/BBL), the calculated flow allowances were added to the calculated BPT flow.

Final Flow (USGAL/BBL) = Calculated U.S. BPT Model Flow + Calculated Flow Allowances

TABLE 5.6

AREAS IN REFINERY WHERE STORM WATER IS TREATED

	REFINERY NAME						
	NOVACOR CORUNNA	SUNCOR SARNIA	SHELL CANADA SARNIA	PETRO CANADA OAKVILLE	ESSO NANTICOKE	ESSO SARNIA	PETRO CANADA MISSISSAUGA
DEVELOPED[a] AREA (ACRES)	23	37	25	15	42	--[b]	117
UNDEVELOPED[c] AREA (ACRES)	73	97	45	34	--	--[b]	149
TOTAL AREA (ACRES)	96	134	70	49	42	240[b]	266
FLOW OF STORM WATER m^3/year	277,124	389,407	203,065	150,507	162,452	692,810	805,093
FLOW OF STORM WATER (IGPM)	116	163	85	63	68	290[b]	337
1989 AVG.[d] DAILY CAPACITY (CRUDE OIL) (BBL/DAY)	46,200[e]	69,668	61,400	66,700	115,500	113,100	41,800
STORM WATER TREATED[f] (USGAL/BBL)	4.0	4.0	2.4	1.6	1.0	4.4	13.9

[a] Area includes; building rooftops, paved areas, process pads, tank roofs, and WWTP units.

[b] Detailed plot plan unavailable for Esso (Sarnia) Ref. - estimate given

[c] Area includes; open fields, green belts, and tank farm areas.

[d] Crude oil only (without other feedstocks).

[e] Novacor processes an additional 25,500 BBL/day of other feedstocks.

[f] Calculation based upon 5-year average precipitation & total area in which storm water is collected & treated.

The calculated flow allowances, calculated U.S. BPT model flows, and final Ontario BPT flows for the seven Ontario refineries are presented in Table 5.7.

TABLE 5.7

ONTARIO BPT FLOWS

	REFINERY NAME						
	NOVACOR CORUNNA	SUNCOR SARNIA	SHELL CANADA SARNIA	PETRO CANADA OAKVILLE	ESSO NANTICOKE	ESSO SARNIA	PETRO CANADA MISSISSAUGA
U.S. EPA SUBCATEGORY	C	C	C	B	B	D	D
STORM WATER TREATED[g] (USGAL/BBL)	4.0	4.0	2.4	1.6	1.0	4.4	13.9
BALLAST WATER TREATED[h] (USGAL/BBL)	0.0	1.1	2.4	0.2	0.40	0.40	0.21
NON-REFINERY SPECIFIC PROCESS[h] (USGAL/BBL)	0.0	0.0	7.0	0.0	0.0	12.3	0.0
CALCULATED U.S. BPT MODEL FLOW (USGAL/BBL)	32	32	27	28	17	72	58
ONTARIO BPT FLOW[i] (USGAL/BBL)	36.0	37.0	39.0	30.0	18.5	89.0	72.0

[g] Calculation based upon 5-year average precipitation & total area in which storm water is collected & treated.

[h] As reported by industry.

[i] Ontario BPT Flow = Calculated U.S. BPT Model Flow + Flow Allowances.

5.2.2 - The Performance Values for Limits

The consultants study of Best Available Technology and comparison of refinery performance (Chapter 4) established that all seven Ontario refineries essentially have BAT in place. The average performance concentrations of contaminants of the seven Ontario refineries is lower than the average performance of the seven best refineries in the U.S. Therefore the consultant suggested that the concentration values for limits be derived from the LTA performance of the Ontario refineries.

Monitoring Data Analysis

Monitoring data were analyzed to assess the performance of Ontario refineries in comparison with other refineries in Canada, U.S., and Europe (Chapter 4). The data were also analyzed for a number of parameters detected in the effluents, concentration levels and frequency of occurrence and compared among the Ontario refineries.

The analysis also included gross outlier checking through time plots for more frequently found parameters. Each refinery's data were assessed separately and the refineries were compared to each other. The analysis showed that, overall, refineries in Ontario achieve similar LTA pollutant concentrations in their final effluents, however, on a monthly, and more importantly, on a daily basis, Ontario refineries' effluent pollutant concentrations vary significantly. From this analysis, it was concluded that limits based on LTA concentrations, along with the reduction of concentration variability on a monthly and daily basis, would result in improved quality of Ontario refineries' effluents.

In order to utilize the performance of Ontario refineries' wastewater treatment plants as a basis for concentration limits, a detailed statistical analysis of the 1989 MISA monitoring data was conducted.

The key steps followed during the statistical data analysis were:

- Data editing of "less than detection level" results
- Estimation of LTA concentration
- Statistical outliers analysis
- Variability analysis
- Setting of performance values

Data Editing

The initial review of the petroleum sector monitoring data revealed that for a large number of parameters (mainly trace organics that were analyzed quarterly) results were "<DL" (less than detection limit) , i. e. the parameter was never found above the detection limit of the laboratory performing the analyses. For these parameters, LTA concentrations and variability factors could not be calculated (eg. 2,3,7,8 TCDD and 2,3,7,8 TCDF). Some trace organics were occasionally detected at, or very close to the detection limit. For example, the parameter was detected in one quarter (trimester) and not detected in the other three. In this case there would be nine "<DL" results and three numerical results. In such

cases "<DL" data were treated in the following way:

- if the result which was reported was less than Laboratory Method Detection Limit (LMDL) and greater than 1/10 RMDL then the value was kept as reported.
- if the result that was reported was less than 1/10 RMDL then the value was replaced by 1/10 RMDL

Estimation of LTA Concentration

A good estimate of LTA concentrations is necessary to set compliance loading limits. When a large number of observations is available, as for daily and thrice-weekly monitored parameters, it provides a representative database encompassing all sources of variability. An LTA based on such data can then be assumed to be an unbiased estimate of the population mean.

An LTA concentration value of the candidate parameters shown in Table 5.3 (with the exception of pH, 2,3,7,8 TCDD and 2,3,7,8 TCDF) was calculated for each refinery as an arithmetic average of all the data collected during monitoring period in that refinery. The LTA values of all refineries were compared parameter by parameter. It was established that, although all refineries have BAT installed, the performance differed from one to another. In addition, the performance in percentage removal of contaminants within one refinery differed from one parameter to another. For example, one refinery achieved good results in TSS and phenolics removal, but poor results in ammonia removal. Therefore, data analysis was performed for each parameter. LTA concentration values from all refineries were averaged to calculate LTA concentrations for the sector. The same was done with the variability factors.

Statistical Outliers Analysis

In order to assess whether the LTA concentration and variability factors are representative of the normal operating conditions, the analysis of extreme values (outliers) was performed. Outlier values may be a result of plant upsets, QA/QC problems, sampling errors or due to unknown causes.

The analytical results of frequently analyzed parameters (daily and thrice-weekly) were plotted against the day on which the sample was analyzed. These plots indicated gross outliers which were further investigated with the refineries to establish if there was an explanation for the erratic behaviour in data or whether it was due to some variability in plant operation that has to be taken in account when establishing compliance limits (start up, change of chemicals - additives, cleaning of equipment).

While gross outlier time plots indicated variability in wastewater treatment performance, statistical tests were performed on the database to establish statistical outliers. Depending on the sample size, two different tests were performed: the Dixon's test and the studentized residual test. A test result greater than 2.326 indicates an outlier and that only high values would be considered as outliers.

The statistical outlier reports were prepared for each refinery and the data were analyzed against process operation to establish whether the outliers were representative of the normal operating conditions. The Monitoring Data Evaluation Subcommittee examined the data and concluded that the statistical outliers were representative of the normal operating conditions and process variations, except for Shell's results for suspended solids.

During the year of monitoring, Shell had a problem with the removal of suspended solids due to the installation and the start up of a new clarifier. The LSS agreed to exclude this refinery's TSS and VSS data from the calculation of the sector's LTA concentrations for TSS and VSS since, due to improper and inconsistent operation of the clarifier, this refinery did not show the BAT performance in solids removal. As far as other parameters are concerned the performance was within BAT performance range. LTA concentrations for other parameters were retained for the calculation of the sector's LTA since they were not affected by the malfunction of the clarifier and they were within the BAT performance range.

Variability Analyses

In order to set a limit which is achievable by a BAT plant, some allowance for variability has to be included. Sources of variability include analytical and sampling uncertainty, process plant variations and treatment process fluctuations that result from changes in raw waste load, flow, and operational changes in treatment system.

The IRC[1] process established two variability factors: one for setting the maximum daily performance value, the daily variability factor - VF_1, and another for setting the monthly average performance value, the monthly variability factor - VF_4 or VF_{30}. The daily maximum and monthly average variability factors are calculated from the fitted probability distribution as the ratio of the 99th percentile and 95th percentile, respectively, to the expected mean.

Table 5.8 shows the comparison of LTA's and variability factors for all seven refineries with outliers included and outliers excluded.

TABLE 5.8

COMPARISON OF LTA'S, VF_1, AND VF_{30} OR VF_4

Parameter	All Refineries (Outliers Included)			All Refineries (Outliers Deleted)		
	LTA (mg/l)	VF_1	VF_4/VF_{30}	LTA (mg/l)	VF_1	VF_4/VF_{30}
Ammonia + Ammonium	1.82	12.32	2.63	1.4	6.02	1.93
DOC	13.20	5.62	1.60	12.0	2.32	1.32
TSS	22.44	5.27	1.20	19.2	3.01	1.45
VSS	14.0	4.38	1.46	12.1	2.72	1.30
Phenolics (4AAP)	0.0112	4.07	1.40	0.0102	2.92	1.33
Sulphide	0.09	6.07	1.91	0.08	2.94	1.49
Oil & Grease	2.42	5.4	1.73	2.11	3.20	1.50

NOTE: VF_{30} used for Phenolics (4AAP) and VSS, since the analyses were done daily.

Setting of Performance Values

An LTA concentration based on BAT performance sets a standard of performance to be expected from plants in compliance on a "long term" basis, such as one year. In order to reflect the variations in a plant's normal operation on a day to day basis, a performance value that includes an allowance for variability has to be established. The performance value is calculated as the product of the average LTA of BAT plants and the average variability factor of BAT plants. The petroleum sector limits are based on the average performance of the seven Ontario refineries.

Although the MDE Subcommittee concluded that all data (MISA monitoring database) for limited parameters, with the exception of TSS and VSS from Shell, represent the normal plant operation over the effluent monitoring period, the LSS reviewed each parameter and applied their BPJ to further reduce the variability of BAT performance values. Therefore, taking into account statistical data analysis results, analysis of performance and BPJ, the LSS derived and adopted the LTA concentrations and variability factors shown in Table 5.9:

TABLE 5.9

CONCENTRATION BASIS FOR LOADING LIMITS

PARAMETER	UNIT	LTA CONCENTRATION	VF_1	VF_4	VF_{30}	MAX. DAILY	MONTHLY AVERAGE
Ammonia + Ammonium	(mg/l)	2	7.5	2.6	—	15	5
DOC	(mg/l)	12	2.9	1.7	—	35	20
Total Phosphorus	(mg/l)	0.37	—	2.7	—	—	1.0
TSS	(mg/l)	15	—	1.5	—	—	23
VSS	(mg/l)	12	2.7	—	1.46	33	18
Phenolics (4AAP)	(µg/L)	11	4.1	—	1.4	45	15
Sulphide	(mg/l)	0.1	3.0	1.5	—	0.3	0.2
Oil and Grease	(mg/l)	5.0	3.2	1.5	—	16	7.5

- TSS BAT LTA and variability factors were based on all data from six refineries excluding Shell data, for the reasons explained earlier. The LTA for six refineries was 15.6 mg/l and the variability factor was 1.67. The LSS agreed to an LTA of 15 and a VF_4 of 1.5.
- PHENOLICS BAT LTA and the variability factors were based on all data from all seven refineries.
- DOC BAT LTA was based on data with outliers excluded and BPJ variability factors.
- AMMONIA BAT LTA was based on all data from all seven refineries, and BPJ variability factors.
- SULPHIDE BAT LTA and the variability factors were based on data with outliers excluded.
- Oil & Grease BAT LTA and the variability factors were based on BPJ.
- VSS BAT LTA and the daily variability factor (VF_1) were based on data with outliers excluded, while the monthly variability factor (VF_4) was based on all data.
- Phosphorus BAT LTA and the variability factor were based on GAP[*] monitoring data for two refineries.

Overall results of the BPJ application were stricter limits and reduced variability.

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[*] GAP monitoring covered the period of December 1, 1989 - April 27, 1992 after the implementation of Chemical Additives Substitution (CAS).

5.3 - THE ONTARIO EFFLUENT LIMITS

The final form of the effluent limits for the Ontario petroleum refining sector developed under the MISA program are presented below along with the procedure for their calculations. The limits are expressed in terms of pollutant loading per day (kg/day) and are presented as maximum daily and monthly average daily compliance limits.

5.3.1 - Daily and Monthly Loading Limits

The loading limits developed under MISA consist of two main components; concentration and flow. The method by which these components were calculated have been discussed previously.

The concentrations for regulated pollutants (Table 5.9) are expressed in terms of **mass of contaminant/volume of wastewater (mg/l or μg/l)**. Flows for Ontario refineries (Table 5.7) are expressed in terms of **volume of wastewater/unit production (USGAL/BBL or m^3/BBL)**. When the two effluent limit components are combined, the result is a **production based loading limit (kg/BBL)**. Thus, in order to arrive at the final **daily loading limit** (kg/day), a production rate (BBL/day) is required.

Reference Production Rate

The production rate utilized in the calculation of the final MISA loading limits is the Reference Production Rate. The petroleum refining sector regulation defines the "reference production rate" as the daily rate of crude oil processed by a direct discharger's plant. This rate is defined in Schedule 4 of the regulation.

According to the Canadian federal regulation[8] for the petroleum refining sector "crude oil" is defined as:

> "virgin or naturally occurring unrefined petroleum and any hydrocarbons or mixture of hydrocarbons similar in composition to petroleum brought into a refinery for processing[**], but does not include hydrocarbons and residual fuels brought into a refinery primarily to meet the fuel requirements of that refinery or primarily for direct blending into finished products"

The LSS selected the average daily capacity of crude oil processed in the highest production month experienced by each Ontario refinery between the years 1986 and 1990 as the reference production rate (RPR) for the petroleum refining sector. This particular production rate was selected to reflect the business cycles of the petroleum refining industry in Ontario. Furthermore, the U.S. EPA recommends the use of monthly production data compiled from a refinery's five year production history for use in calculating BPT Effluent Limitations Guidelines[9]. Table 5.10 shows the RPR for each refinery.

[**] Novacor processes up to 25,500 BBL/day of such feedstock in addition to crude oil.

TABLE 5.10

REFERENCE PRODUCTION RATE FOR EACH REFINERY

REFINERY	REFERENCE PRODUCTION RATE	
	m^3/day	BBL/day
ESSO - SARNIA	19,900	125,000
ESSO - NANTICOKE	18,600	117,000
PETRO-CANADA - MISSISSAUGA	7,300	46,000
PETRO-CANADA - OAKVILLE	11,600	73,000
SHELL - SARNIA	11,300	71,000
SUNCOR - SARNIA	11,900	75,000

The final MISA effluent loading limits for the petroleum refining sector are calculated utilizing the following formulae:

Daily Loading Limit (kg/day) = **LTA x VF_1 x Ontario BPT Flow x RPR**

Monthly Average Limit (kg/day) = LTA x VF_4 (or VF_{30}) x Ontario BPT Flow x RPR

The final daily and monthly effluent loading limits for each of the Ontario petroleum refineries are presented in Tables 5.11 and 5.12, respectively.

TABLE 5.11

FINAL DAILY LOADING LIMITS (KG/DAY)

DAILY LIMITS	REFINERY						
PARAMETER	Esso Sarnia	Esso Nant.	Novacor	Petro-Can Miss.	Petro-Can Oak.	Shell	Suncor
Ammonia + Ammonium	632	123	188	188	124	157	158
DOC	1,465	285	436	436	288	365	366
VSS	1364	265	406	406	269	340	340
Phenolics (4AAP)	1.90	0.37	0.57	0.57	0.37	0.47	0.47
Sulphide	12.6	2.5	3.8	3.8	2.5	3.1	3.2
Oil & Grease	674	131	201	201	133	168	168

TABLE 5.12

FINAL MONTHLY LOADING LIMITS (KG/DAY)

MONTHLY LIMITS	REFINERY						
PARAMETER	Esso Sarnia	Esso Nant.	Novacor	Petro-Can Miss.	Petro-Can Oak.	Shell	Suncor
Ammonia + Ammonium	219	43	65	65	43	55	55
DOC	859	167	256	256	169	214	214
Total Phosphorus	41	8	12	12	8	10	10
TSS	947	184	282	282	187	236	236
VSS	738	144	220	220	145	184	184
Phenolics (4AAP)	0.65	0.13	0.19	0.19	0.13	0.16	0.16
Sulphide	6.3	1.2	1.9	1.9	1.2	1.6	1.6
Oil & Grease	316	61	94	94	62	79	79

5.3.2 - "Not to Exceed" Concentration Limits

The daily "not to exceed" concentration limits were developed for three regulated parameters. The "not to exceed" limits were calculated by multiplying the LTA concentration for each parameter by the square of the parameter's daily variability factor. This approach assumes that the square of the variability factor will take into account all of the variability that may occur within the day. Table 5.13 lists the "not to exceed" concentrations for each parameter to be limited.

TABLE 5.13

"NOT TO EXCEED" CONCENTRATION LIMITS

ATG	PARAMETER	"NOT TO EXCEED" CONCENTRATION
5a	Dissolved Organic Carbon	110.0 mg/l
14	Phenolics (4AAP)	0.2 mg/l
25	Oil and Grease	50.0 mg/l

5.4 - OVERALL IMPLICATIONS OF MISA EFFLUENT LIMITS FOR ONTARIO REFINERIES

Although the Ontario refineries have been identified as having BAT in place, improvements can be made in the operation of petroleum refining wastewater treatment systems. Steps can be taken to maintain low pollutant concentrations in final effluent and eliminate high daily and monthly concentration fluctuations. Furthermore, as optimum BAT performance is achieved, continued pollutant reductions will occur within the refinery, through the application of reduce, reuse, and recycle techniques and other pollution prevention measures (i.e. best management practices or use of alternate technology).

Although some of the U.S. refineries have demonstrated water use below that of BPT, the loading of pollutants from the Ontario refineries will be far less than their U.S. counterparts as a result of the substantially lower variability and concentrations used for developing MISA loading limits.

The implementation of the MISA loading limits based upon a sector average will bring all Ontario refinery wastewater treatment plants to a common level of operation, help reduce the variability of operation, and overall, the amount of pollutants entering Ontario waterways.

Table 5.14 presents a summary of the estimated loading removal for the limited parameters after the implementation of the regulation. The loadings are expressed in kilograms per year and reflect the total loading from the petroleum refining sector.

Likewise, table 5.15 presents a summary of the estimated loading removal for selected non-limited parameters.

- Zinc and chromium are reduced through the application of CAS

- Organic compounds are reduced as a result of flow reduction

TABLE 5.14

LOADING REMOVAL SUMMARY (kg/year) (FOR LIMITED PARAMETERS)

PARAMETER	INITIAL LOADING (MISA 1989)	FINAL LOADING	TOTAL LOADING REMOVED	PERCENT REMOVAL %
Ammonia + Ammonium	30,180	26,970	3,210	11
DOC	328,320	277,770	50,550	15
Total Phosphorus	17,650	6,430	11,220	64
TSS	565,600	345,000	220,600	39
VSS	365,200	253,000	112,200	31
Phenolics (4AAP)	210	160	50	24
Sulphide	1,630	1,433	197	12
Oil and Grease	57,570	53,490	4,080	7

TABLE 5.15

LOADING REMOVAL OF SELECTED NON-LIMITED PARAMETERS (kg/year)

PARAMETER	INITIAL LOADING (MISA 1989)	FINAL LOADING	TOTAL LOADING REMOVED	PERCENT REMOVAL %
Zinc	4,420	770	3,650	83
Chromium	1,414	724	690	49
BTX*** (Total)	140	77	63	45

*** BTX = Benzene, Toluene, and o-, m- & p-Xylene

5.5 - REFERENCES

1. Ontario Ministry of the Environment. MISA Issue Resolution Process Issue Resolution Report. Toronto, Ontario. June 1990.

2. Ontario Ministry of the Environment. Report on the Analysis of the Quality Assurance and Quality Control Data for the Petroleum Refining Sector. Water Resources Branch - MISA Industrial Office, Toronto, Ontario. July 1992.

3. Ontario Ministry of the Environment. Candidate Substances List for Bans and Phase-outs. Toronto, Ontario. April 1992.

4. The United States Environmental Protection Agency (1982). Development Document for Effluent Limitations Guidelines New Source Performance Standards and Pretreatment Standards for the Petroleum Refining Point Source Category. Effluent Guidelines Division - Office of Water Regulations and Standards. Washington D.C. 1982.

5. The United States Environmental Protection Agency (1974). Development Document for Effluent Limitations Guidelines New Source Performance Standards and Pretreatment Standards for the Petroleum Refining Point Source Category. Effluent Guidelines Division - Office of Water Regulations and Standards. Washington D.C. 1974.

6. Federal Register - The United States Environmental Protection Agency. 40 CPR 419 - Petroleum Refining Point Source Category Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards, Subpart D. Vol.44. No. 201. Washington D.C. October 18, 1982.

7. Science Applications International Corporation. Best Available Technology For The Ontario Petroleum Refining Sector. Ontario Ministry of the Environment. April 1992.

8. Environment Canada, Environmental Protection Services. Petroleum Refinery Effluent Regulations and Guidelines. Ottawa, Ontario. January 1974.

9. The United States Environmental Protection Agency. Guide for the Application of Effluent Limitations Guidelines for the Petroleum Refining Industry. Pgs. # 122-123. Washington D.C. June 1985.

CHAPTER 6

THE EFFLUENT LIMITS REGULATION

CHAPTER 6

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6.0 - THE EFFLUENT LIMITS REGULATION

The Effluent Limits Regulation for the Petroleum Refining Sector establishes the terms and conditions of compliance. The regulation consists of sixteen sections, which cover definitions, compliance, requirements related to compliance, requirements related to pre-compliance, record keeping, reporting and timing.

6.1 - SECTIONS OF THE REGULATION

Definitions

Section 1 provides definitions of terms used in the Regulation in order to clarify the meaning of those terms which may have different interpretations and to explain technical terms which may not be in common usage.

Purpose

The purpose of the Effluent Limits Regulation is to control the quality of effluents that are discharged directly to surface watercourses by the petroleum refineries in Ontario. This will be done by limiting the concentrations and loadings of the specified substances in refinery process effluent and by requiring that the process effluent be non-acutely lethal to the aquatic species specified in the Regulation.

Process effluent is defined by the Regulation as an effluent - wastewater stream - which originates from contact with any industrial process or process materials.

The Limits Regulation will also require that the discharge of all once-through cooling water (OTCW) effluent streams be monitored for assessment, in order to ensure that these streams are not contaminated and acutely lethal to the aquatic species specified in the regulation.

OTCW is defined by the Regulation as water that is used only once in an industrial process for removing heat and, by design, does not come into contact with process materials.

Application

The Regulation applies to the seven direct discharge petroleum refineries in Ontario listed in Schedule 1 of the Regulation.

Compliance

The compliance requirements of the Regulation come into effect three (3) years after the Regulation is promulgated. The regulated limits listed in Schedule 2 of the Regulation apply to process effluent. If a refinery fails to comply with the requirements of Schedule 2 and a limit is exceeded, the event could be subject to enforcement by the Ministry. The Regulation contains the following types of process effluent limits:

1) "Not to exceed" concentration limits. The concentration limits listed in Column 3 of Schedule 2 must not be exceeded at any time while a refinery is discharging process effluent. In order to ensure compliance with these limits, the Ministry will periodically collect process effluent samples from each refinery and measure the concentration of each parameter for which there is a concentration limit.

2) Daily plant loading limits. A refinery must not exceed the daily plant loading limits listed in Column 4 of Schedule 2 on any operating day.

3) Monthly average plant loading limits. A refinery must not exceed the monthly average plant loading limits listed in Column 5 of Schedule 2 during any month of the year.

4) pH. A refinery must not discharge process effluent that has a pH below 6.0 or above 9.5 at any time.

5) Acute lethality. A refinery must not discharge an effluent that is acutely lethal to either rainbow trout or Daphnia magna. An acutely lethal effluent is one that kills more than 50 percent of the test species in 100 percent (undiluted) effluent.

By-Passes

The Regulation requires that all refinery effluent must be discharged through designated sampling points only, thereby prohibiting the discharge through by-passes.

Sampling Points

A discharger must designate sampling points on all process effluent and once-through cooling water effluent streams. The sampling point location has to be representative of the effluent's characteristics. All samples collected for the Regulation must be taken from designated sampling points.

Sampling and Analytical Procedures

In order to ensure the accurate sampling and analysis of effluent samples, standard sampling and analytical procedures have been developed by the Ministry. The Ministry protocol on sampling and analysis[1] outlines how a discharger must collect a sample, how the sample should be analyzed, and the minimum analytical method detection level that the laboratory must meet when analyzing the sample.

Each discharger must ensure that all sampling equipment is maintained properly in order to ensure that a representative sample is always collected.

Calculation of Loadings

Daily Plant Loadings. In order to determine compliance with the daily plant loading limits, a daily plant loading for each limited parameter must be calculated. This is done by multiplying the analytical concentration result of the monitored parameter by the flow rate of the monitored effluent stream for the day of sampling. The following rules must be observed when calculating parameter loadings:

- If the parameter was not detected in the effluent and the laboratory method detection limit (LMDL) for the parameter is greater than or equal to 1/10th of the analytical method detection limit (RMDL), listed in the Ministry protocol on sampling and analysis[1], then the value of the LMDL must be used.

- If the parameter was not detected in the effluent and the LMDL for the parameter is less than 1/10th of the RMDL, listed in the Ministry protocol on sampling and analysis[1], then the value of zero must be used.

Daily plant loading shall be calculated for both process and OTCW effluents for the parameters listed in schedules 2 and 3 respectively.

Monthly Average Plant Loadings. In order to determine compliance with the monthly average plant loading limits, a monthly average plant loading for each limited parameter must be calculated. This is done by taking the average (arithmetic mean) of the daily plant loadings reported for the month. The calculation shall be performed as soon as the analytical results are available.

Monthly plant loading shall be calculated for both process and OTCW effluents for the parameters listed in schedules 2 and 3 respectively. The calculation shall be performed as soon as is reasonably possible after the end of the month in which daily plant loadings are calculated.

Effluent Volumes. A discharger must calculate the daily plant volume of process effluent that is discharged from each process effluent stream each day that the refinery is in operation. The discharger must also calculate the daily plant volume of once-through cooling water effluent that is discharged from each OTCW effluent stream on the days that once-through cooling water effluent samples are collected.

At the end of each month the discharger must calculate the monthly average volume of effluent discharged during the month by taking the average (arithmetic mean) of the daily plant volumes reported for the month.

Calculation of average pH. A discharger shall calculate the monthly average pH value for each process effluent stream. Monthly average pH value is calculated as the arithmetic mean of the pH values for all samples collected for the process effluent throughout the month. The calculation shall be performed as soon as is reasonably possible after the end of the month in which the daily pH values are determined.

Limits Monitoring

Parameters. Petroleum Refining Sector dischargers must monitor process effluent for the following chemical parameters:

- pH
- Ammonia plus Ammonium
- Dissolved Organic Carbon (DOC)
- Total Phosphorous
- Total Suspended Solids
- Volatile Suspended Solids (VSS)
- Phenolics (4AAP)
- Sulphide
- 2,3,7,8-Tetrachlorinated dibenzo-p-dioxin
- 2,3,7,8-Tetrachlorinated dibenzofuran
- Oil and grease

Process Effluent. Each discharger is required to collect 24-hour composite samples of process effluent daily, weekly, and quarterly. The daily, weekly, and quarterly samples must be analyzed for the parameters for which the frequency of monitoring is indicated in Column 2 of Schedule 2 as being daily, weekly, and quarterly respectively. The frequency of monitoring for each limited parameter is shown in Table 6.1.

TABLE 6.1

MONITORING FREQUENCY FOR LIMITED PARAMETERS

ATG	Parameter	Frequency
3	pH	Daily
4a	Ammonia plus Ammonium	Weekly
5a	Dissolved Organic Carbon (DOC)	Weekly
6	Total Phosphorus	Weekly
8	TSS	Weekly
	VSS	Daily
14	Phenolics (4AAP)	Daily
15	Sulphide	Weekly
24	2,3,7,8-tetrachlorinated dibenzo-p-dioxin	Quarterly
	2,3,7,8-tetrachlorinated dibenzofuran	Quarterly
25	Oil and grease	Weekly

For the purpose of reporting pH, a discharger must collect three grab samples daily, no sooner than six hours apart, analyze each sample for pH and calculate an average value.

Assessment Monitoring - OTCW

OTCW effluent has to be monitored once per week for assessment purposes. Table 6.2 lists the parameters that have to be monitored.

TABLE 6.2

ONCE-THROUGH COOLING WATER EFFLUENT ASSESSMENT MONITORING PARAMETERS

ATG	Parameter
14	Phenolics (4AAP)
15	Sulphide
17	Benzene
	Toluene

Quality Control Monitoring

Once a year each discharger shall:

- prepare and analyze a travelling blank sample for all the limited parameters except pH, TSS and VSS.
- collect from the process effluent sampling point a duplicate or replicate sample and analyze for all of the limited parameters.

The samples for quality control monitoring must be collected on the same day as the regular compliance monitoring samples for the limited parameters. Procedures for collecting these quality control samples are outlined in the Ministry of the Environment "Protocol for the Sampling and Analysis of Industrial/Municipal Wastewater[1]".

Acute Lethality Testing

During the first year that the Regulation is in effect, each discharger is required to conduct monthly acute lethality tests in order to determine whether the refinery's process effluent or once-through cooling water effluent is acutely lethal to rainbow trout or Daphnia magna. The Environment Canada protocols on acute toxicity testing[2,3] describe the sampling and analytical procedures that have to be followed when conducting the acute lethality tests.

If a refinery passes twelve consecutive acute lethality tests, then the discharger is allowed to monitor acute lethality on a quarterly basis.

Chronic Toxicity Testing

When a refinery passes twelve consecutive acute lethality tests and begins to perform the tests quarterly, a discharger is required to monitor chronic toxicity to Ceriodaphnia dubia and fathead minnows, once every six months. These 7-day tests study Ceriodaphnia dubia reproduction inhibition and survivability and fathead minnow growth inhibition in 100% process effluent and 100% once-through cooling water. The Environment Canada protocols on chronic toxicity testing[4,5] describe the sampling and analytical procedures that have to be followed when conducting the chronic toxicity tests.

Flow Measurement

In order to determine daily and monthly plant loadings, each discharger must continuously measure the daily flow of all process effluent streams. Each flow measurement device must:

- be installed properly and be easily accessible for inspection by a provincial officer; and,
- be accurate to within ±15%.

Each discharger must also measure the flow of once-through cooling water on the day that samples are collected. Each flow measurement device must:

- be maintained in the same manner as the process effluent flow measurement devices; and,
- be accurate to within ±20%.

Storm Water Control Study

Each discharger must complete a storm water control study within four years after the Regulation comes into force according to the Ministry of the Environment protocol for conducting a storm water control study[6]. The discharger may be exempted from a storm water control study if they qualify for exemption as specified in the protocol.

Record Keeping

Each discharger must keep all records, specified by the regulation, for a period of five years and upon request, make them accessible to the Ministry for inspection.

Following records must be kept:

- Sampling point locations, sampling and analytical procedures used, date and time of each sample collection, and any incident that may affect the analytical result
- All the calculations of loadings, pH and effluent volumes
- All results of process effluent, OTCW effluent, and quality control monitoring
- All results of acute lethality and chronic toxicity testing
- All records of flow measurement as well as records of maintenance and calibration of flow measuring devices
- All problems of malfunction related to sampling, chemical analysis, acute lethality and chronic toxicity testing, and flow measuring devices detailing date and duration of malfunction and remedial action taken
- Any discharges of process or OTCW effluent that is not discharged through a stream on which a sampling point has been designated, with details on the date, duration, cause and nature of discharge
- All process changes that affect quality of process and OTCW effluents
- Daily production rate which includes crude oil processed and/or other feedstock similar to crude oil, brought to the refinery for processing but not for blending into final products

Reporting

Each discharger shall report to the Ministry:

- any change of name or ownership of the refinery occurring after the regulation is filed
- all process changes that permanently affect the character and quality of any effluent streams
- change in production rate - if the refinery has operated at less than 75% of the reference production rate, specified in Schedule 4, for more than 90 consecutive days.
- Compliance A discharger shall notify the Ministry, as soon as the results are available, about all non-compliance events:
  - Exceedance of "never to exceed" concentrations as specified in Schedule 2
  - Exceedance of the daily and/ or monthly plant loadings as specified in Schedule 2
  - pH of process effluent is outside the range specified by the regulation
  - Failure to meet the acute lethality test for either process or OTCW effluents
- Loadings: A discharger shall report monthly average plant loadings, and the maximum and minimum daily loadings for those parameters specified in Schedules 2 and 3 for process effluent and OTCW effluent respectively. The loadings must be reported no later than 45 days after the end of the quarter to which the loadings relate.
- By-passes: A discharger shall report any discharge of process effluent or OTCW effluent that is not discharged through a process effluent or OTCW effluent sampling point.
- Flow measurement: A discharger shall report monthly average plant volume, and the maximum and minimum daily plant volume of process effluent and OTCW effluent. The plant volume must be reported no later than 45 days after the end of the quarter to which the flow was measured.
- Chronic toxicity: all tests results within 60 days after the semi-annual period in which the samples were collected.

Each direct discharger shall prepare an annual summary of all test results (concentration, flow and toxicity) and all non-compliance events, on or before June 1st of each year, and make it available to the public.

Timing

The regulation applies to the seven refineries, listed in Schedule 1, on the day it is filed.

Each discharger must start to follow the monitoring and reporting requirements 90 days after the Regulation has been filed.

The compliance with limits comes into effect on the first day of the fourth year after the Regulation has been filed.

6.2 - NEW PLANTS

This regulation applies only to the seven existing Ontario refineries which are listed in Schedule 1. The regulation does not apply to the new plants that may be built in the future.

Loading limits for new plants will be established by the Ministry when an application for approval to construct the new plant is received. These limits will be established on the basis of "Best in the World" demonstrated technology, using its performance data for flow and effluent concentrations. It is expected that the requirements for new refineries in Ontario will be stricter than the requirements of this current regulation because a new refinery can be designed to incorporate water conservation practices together with the best wastewater treatment technologies.

As a minimum, a new refinery would have to meet limits based on a BPT flow requirement of 50% of the U.S. BPT flow.

6.3 - REFERENCES

1. Ontario Ministry of the Environment (1991). "Protocol for the Sampling and Analysis of Industrial/Municipal Wastewater". Toronto, Ontario.

2. Environment Canada (1990). "Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout". Toronto, Ontario.

3. Environment Canada (1990). "Reference Method for Determining Acute Lethality of Effluents to Daphnia magna". Toronto, Ontario.

4. Environment Canada (1992). Test of Reproduction and Survival Using the Cladoceran Ceriodaphnia dubia". Toronto, Ontario.

5. Environment Canada (1992). "Test of Larval Growth and Survival Using Fathead Minnows". Toronto, Ontario.

6. Ministry of the Environment (1992). "MISA Protocol For Conducting A Storm Water Control Study". Toronto, Ontario.

APPENDIX A

SUMMARY TABLES OF MONITORING RESULTS FOR PROCESS EFFLUENT STREAMS

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APPENDIX A

TABLE A1.0
PROCESS EFFLUENT STREAMS
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ALL SEVEN REFINERIES

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
COD	84	100	8.000	269.000	49.238	mg/l
DOC	1096	100	.300	256.000	13.184	mg/l
Hydrogen ion (pH)	2521	100	6.200	9.200	7.673	
Specific conductance	84	100	442.000	2,830.000	1,405.571	µS/cm
TOC	952	100	.700	308.000	19.559	mg/l
Total Kjeldahl nitrogen	79	99	.100	19.500	2.281	mg/l
Total suspended solids	1547	99	1.900	1,038.000	26.862	mg/l
VSS	2487	98	1.000	666.000	14.038	mg/l
Nitrate+Nitrite	78	96	.025	13.900	2.686	mg/l
Zinc	654	95	1.000	31,200.000	465.498	µg/l
Aluminum	83	92	3.000	2,700.000	334.759	µg/l
Phenolics (4AAP)	2510	92	.200	296.000	11.269	µg/l
Total phosphorus	1091	88	.010	34.800	.475	mg/l
Arsenic	83	86	2.000	38.000	8.767	µg/l
Cyanide Total	81	80	.001	.085	.010	mg/l
Ammonia plus Ammonium	1204	79	.025	70.000	1.699	mg/l
Chromium	650	79	2.000	690.000	112.886	µg/l
Oil and grease	1200	77	.100	18.700	2.503	mg/l
Sulphide	1165	71	.002	.870	.084	mg/l
Chromium (hexavalent)	12	67	3.100	31.000	13.033	µg/l
Selenium	83	60	.500	24.000	5.467	µg/l
Molybdenum	83	41	4.800	116.000	21.299	µg/l
Nickel	83	39	3.000	30.000	10.592	µg/l
Chloroform	85	38	.200	14.600	.980	µg/l
Copper	83	36	3.000	140.000	9.517	µg/l
Vanadium	83	31	3.000	140.000	16.159	µg/l
Antimony	83	28	.500	14.000	2.328	µg/l
Bis(2-ethylhexyl) phthalate	35	23	1.400	11.000	1.879	µg/l
Methylene chloride	85	22	.300	33.000	1.532	µg/l
Cobalt	83	18	3.000	75.000	10.527	µg/l
Toluene	1094	18	.050	33.800	.699	µg/l
Benzene	1095	17	.100	82.223	.756	µg/l
Mercury	83	16	.019	.150	.076	µg/l
o-Xylene	1095	16	.050	101.900	1.136	µg/l
Chloromethane	85	14	.370	13.800	3.106	µg/l
Di-n-butyl phthalate	35	14	1.100	2.200	1.357	µg/l
Thallium	83	14	9.000	310.000	34.976	µg/l
m-Xylene and p-Xylene	1094	14	.110	62.200	.931	µg/l
Cadmium	83	13	.200	9.000	2.660	µg/l
Octachlorodibenzo-p-dioxin	16	13	.071	.650	.146	ng/l
Lead	83	10	3.000	230.000	20.542	µg/l
1,2-Dichloropropane	85	9	.200	27.000	.897	µg/l
Benzylbutylphthalate	35	9	.500	12.000	.989	µg/l
Phenol	83	8	.240	9.560	1.245	µg/l
Anthracene	83	7	.120	1.000	.436	µg/l
PCBT	14	7	10.000	5,200.000	413.929	ng/l
Total H7CDD	15	7	.020	.200	.073	ng/l
1,1-Dichloroethylene	85	6	.280	2.170	.832	µg/l
1,2,3,4-Tetrachlorobenzene	16	6	.003	.200	.020	µg/l
1,2-Dichloroethane	85	6	.200	2.100	.672	µg/l
2,4,5-Trichlorotoluene	16	6	.002	.010	.005	µg/l
Bromomethane	85	6	.830	19.800	3.447	µg/l
Hexachlorobenzene	16	6	.003	.100	.011	µg/l
Octachlorostyrene	16	6	.003	.140	.013	µg/l
Pyrene	83	6	.100	.630	.344	µg/l

(Table A1.0 continued on next page)

TABLE A1.0 (continued)
PROCESS EFFLUENT STREAMS
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ALL SEVEN REFINERIES

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Silver	83	6	3.000	20.000	8.091	µg/l
Styrene	85	6	.164	1.443	.299	µg/l
Total PCDF	16	6	.020	.300	.143	ng/l
Total TCDF	16	6	.020	.300	.147	ng/l
2-Methylnaphthalene	83	5	.220	42.500	1.769	µg/l
Chrysene	83	5	.150	.430	.291	µg/l
Ethylbenzene	1095	5	.060	24.300	.347	µg/l
1,1-Dichloroethane	85	4	.200	.600	.418	µg/l
2,4-Dimethylphenol	83	4	.730	8.140	1.469	µg/l
Phenanthrene	83	4	.200	2.830	.374	µg/l
o-Cresol	83	4	.566	2.350	1.528	µg/l
p-Cresol	80	3	.449	3.600	2.059	µg/l
4-Nitrophenol	83	2	.375	2.400	1.158	µg/l
Acenaphthene	83	2	.200	4.000	.770	µg/l
Benz(a)anthracene	83	2	.100	.500	.307	µg/l
Benzo(b)fluoranthene	83	2	.200	2.600	.471	µg/l
m-Cresol	83	2	.433	3.000	1.813	µg/l
1,1,2-Trichloroethane	82	1	.200	.860	.472	µg/l
1-Methylnaphthalene	83	1	.320	2.200	1.506	µg/l
4-Chloro-3-methylphenol	83	1	.150	4.220	1.170	µg/l
Acenaphthylene	83	1	.400	1.000	.615	µg/l
Dibromochloromethane	85	1	.110	1.010	.499	µg/l
Fluorene	83	1	.200	4.420	.613	µg/l
Indeno(1,2,3-cd)pyrene	83	1	.600	1.300	.896	µg/l
Naphthalene	83	1	.300	2.000	1.065	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

APPENDIX A

TABLE A1.1
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Arsenic	12	100	2.000	13.000	8.333	µg/l
COD	12	100	28.000	41.000	34.750	mg/l
Hydrogen ion (pH)	352	100	7.000	8.400	7.629	
Nitrate+Nitrite	12	100	3.690	8.350	6.009	mg/l
Specific conductance	12	100	654.000	916.000	783.750	µS/cm
TOC	157	100	2.300	88.000	14.032	mg/l
Total Kjeldahl nitrogen	10	100	.810	1.260	.994	mg/l
Total suspended solids	148	100	1.900	46.200	12.778	mg/l
DOC	157	99	.500	17.000	9.600	mg/l
VSS	332	99	1.000	56.700	10.985	mg/l
Total phosphorus	152	96	.020	34.800	1.056	mg/l
Ammonia plus Ammonium	157	94	.090	11.000	.563	mg/l
Cyanide Total	12	92	.005	.085	.015	mg/l
Selenium	12	92	2.000	24.000	15.833	µg/l
Zinc	12	92	1.000	42.000	18.250	µg/l
Sulphide	157	87	.002	.600	.042	mg/l
Aluminum	12	83	3.000	384.000	90.667	µg/l
Phenolics (4AAP)	351	83	2.000	19.000	3.501	µg/l
Toluene	151	60	.200	17.100	1.924	µg/l
Benzene	151	56	.100	21.900	1.840	µg/l
m-Xylene and p-Xylene	151	51	.110	55.300	2.449	µg/l
o-Xylene	151	51	.200	29.700	1.636	µg/l
Methylene chloride	12	42	.500	1.900	.742	µg/l
1,2-Dichloroethane	12	25	.200	.400	.233	µg/l
Nickel	12	25	10.000	30.000	11.667	µg/l
Oil and grease	157	21	1.000	9.700	1.195	mg/l
Ethylbenzene	151	19	.200	24.300	.807	µg/l
Cadmium	12	17	2.000	3.000	2.083	µg/l
Chloroform	12	17	.200	.500	.233	µg/l
Vanadium	12	17	20.000	70.000	25.833	µg/l
Antimony	12	8	2.000	9.000	2.583	µg/l
Copper	12	8	10.000	14.000	10.333	µg/l
Lead	12	8	30.000	40.000	30.833	µg/l
Phenol	12	8	1.000	3.300	1.192	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A1.2
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT PETRO-CANADA INC., LAKE ONTARIO REFINERY - MISSISSAUGA PLANT

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Aluminum	11	100	65.000	620.000	267.455	µg/l
Antimony	11	100	.900	3.100	1.618	µg/l
Arsenic	11	100	2.000	12.000	5.364	µg/l
COD	12	100	20.000	84.000	44.083	mg/l
DOC	155	100	4.000	46.500	12.654	mg/l
Hydrogen ion (pH)	364	100	6.600	9.200	7.435	
Molybdenum	11	100	5.000	110.000	35.000	µg/l
Nickel	11	100	3.000	11.000	7.509	µg/l
Nitrate+Nitrite	12	100	.039	3.410	.588	mg/l
Specific conductance	12	100	515.000	789.000	639.083	µS/cm
TOC	155	100	3.700	56.000	19.445	mg/l
Total Kjeldahl nitrogen	12	100	.600	5.180	1.995	mg/l
Total suspended solids	258	100	4.700	551.200	26.215	mg/l
VSS	361	100	1.000	391.200	15.416	mg/l
Chromium	160	99	2.000	550.000	126.013	µg/l
Oil and grease	156	97	.710	18.700	4.497	mg/l
Zinc	159	97	7.000	1,270.000	91.403	µg/l
Sulphide	157	96	.010	.870	.099	mg/l
Ammonia plus Ammonium	155	95	.040	70.000	3.756	mg/l
Phenolics (4AAP)	362	94	1.800	71.000	8.901	µg/l
Vanadium	11	91	5.000	140.000	48.545	µg/l
Chloroform	12	67	.300	14.600	2.766	µg/l
Cyanide Total	12	58	.001	.012	.004	mg/l
Total phosphorus	155	58	.060	3.100	.221	mg/l
Selenium	11	55	1.400	2.500	1.736	µg/l
Copper	11	45	6.000	8.300	7.755	µg/l
Mercury	11	36	.100	.150	.105	µg/l
Thallium	11	36	9.000	310.000	99.909	µg/l
Cobalt	11	27	3.000	5.000	3.273	µg/l
Lead	11	27	8.000	230.000	29.455	µg/l
Silver	11	18	3.000	3.000	3.000	µg/l
Styrene	12	17	.200	1.443	.353	µg/l
o-Xylene	156	11	.100	20.500	.609	µg/l
Benzene	156	10	.100	1.690	.153	µg/l
Cadmium	11	9	6.000	9.000	6.273	µg/l
Phenanthrene	11	9	.200	.640	.313	µg/l
Pyrene	11	9	.200	.630	.312	µg/l
m-Xylene and p-Xylene	156	9	.110	22.000	.560	µg/l
Dibromochloromethane	12	8	.110	1.010	.283	µg/l
Methylene chloride	12	8	.400	13.550	1.612	µg/l
Toluene	156	5	.100	1.060	.126	µg/l
Ethylbenzene	156	1	.200	.200	.200	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A1.3
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT PETRO-CANADA INC., LAKE ONTARIO REFINERY - OAKVILLE PLANT

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Ammonia plus Ammonium	156	100	1.100	23.100	4.859	mg/l
Arsenic	12	100	5.000	34.000	15.975	µg/l
COD	12	100	63.000	269.000	103.833	mg/l
Chromium	155	100	17.000	690.000	88.471	µg/l
DOC	155	100	8.800	72.000	17.911	mg/l
Hydrogen ion (pH)	364	100	7.200	9.000	8.042	
Molybdenum	12	100	9.000	116.000	29.500	µg/l
Nickel	12	100	3.000	16.000	6.183	µg/l
Nitrate+Nitrite	12	100	.127	.471	.257	mg/l
Octachlorodibenzo-p-dioxin	2	100	.071	.650	.361	ng/l
Phenolics (4AAP)	365	100	8.000	296.000	42.362	µg/l
Specific conductance	12	100	1,690.000	2,280.000	2,011.667	µS/cm
Sulphide	156	100	.040	.400	.168	mg/l
TOC	155	100	13.000	100.000	26.954	mg/l
Total Kjeldahl nitrogen	12	100	1.510	19.500	6.640	mg/l
Total suspended solids	159	100	5.000	191.000	22.340	mg/l
VSS	364	100	4.000	47.000	14.503	mg/l
Oil and grease	156	99	.350	18.200	2.460	mg/l
Zinc	155	99	7.000	31,200.000	1,419.723	µg/l
Total phosphorus	155	97	.062	3.680	.774	mg/l
Aluminum	12	83	6.000	434.000	178.750	µg/l
Antimony	12	83	.500	1.200	.700	µg/l
Cyanide Total	12	75	.001	.009	.006	mg/l
Selenium	12	75	.500	13.600	5.642	µg/l
1,2,3,4-Tetrachlorobenzene	2	50	.010	.200	.105	µg/l
2,4,5-Trichlorotoluene	2	50	.010	.010	.010	µg/l
Anthracene	12	50	.120	.540	.310	µg/l
Bis(2-ethylhexyl) phthalate	2	50	1.700	3.070	2.385	µg/l
Hexachlorobenzene	2	50	.010	.100	.055	µg/l
Octachlorostyrene	2	50	.010	.140	.075	µg/l
PCBT	2	50	100.000	5,200.000	2,650.000	ng/l
Total PCDF	2	50	.020	.024	.022	ng/l
Total TCDF	2	50	.020	.065	.042	ng/l
1,2-Dichloropropane	13	46	.500	3.900	1.470	µg/l
Chloromethane	13	46	3.500	13.800	6.647	µg/l
Pyrene	12	33	.200	.520	.337	µg/l
o-Xylene	156	26	.100	101.900	4.119	µg/l
2,4-Dimethylphenol	12	25	.730	8.140	2.232	µg/l
2-Methylnaphthalene	12	25	.500	42.500	4.155	µg/l
Cobalt	12	25	3.000	75.000	11.000	µg/l
Phenol	12	25	.900	9.560	2.500	µg/l
Silver	12	25	3.000	3.000	3.000	µg/l
o-Cresol	12	25	.700	2.350	1.343	µg/l
Bromomethane	13	23	3.700	19.800	7.346	µg/l
Styrene	13	23	.200	1.260	.366	µg/l
Benzene	156	20	.100	55.400	.897	µg/l
Acenaphthene	12	17	.200	4.000	.968	µg/l
Lead	12	17	8.000	12.000	9.167	µg/l
m-Cresol	12	17	.600	1.000	.792	µg/l
p-Cresol	12	17	.600	1.900	.967	µg/l
1,1-Dichloroethylene	13	15	1.700	2.170	1.752	µg/l
Methylene chloride	13	15	.400	.850	.464	µg/l
m-Xylene and p-Xylene	156	15	.110	62.200	1.112	µg/l
Toluene	156	10	.100	33.800	.562	µg/l
1,1,2-Trichloroethane	13	8	.500	.860	.528	µg/l

(Table 2.3 continued on next page)

TABLE A1.3 (continued)
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT PETRO-CANADA INC., LAKE ONTARIO REFINERY - OAKVILLE PLANT

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
1-Methylnaphthalene	12	8	.400	1.530	.694	µg/l
4-Chloro-3-methylphenol	12	8	1.300	4.220	1.593	µg/l
4-Nitrophenol	12	8	.900	2.400	1.233	µg/l
Acenaphthylene	12	8	.400	.800	.533	µg/l
Cadmium	12	8	1.000	6.000	4.333	µg/l
Chrysene	12	8	.300	.330	.302	µg/l
Copper	12	8	8.000	8.000	8.000	µg/l
Fluorene	12	8	.200	4.420	.802	µg/l
Naphthalene	12	8	.700	1.800	1.298	µg/l
Phenanthrene	12	8	.200	2.830	.519	µg/l
Ethylbenzene	156	1	.200	3.180	.228	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A1.4
PROCESS EFFLUENT STREAM CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT NOVACOR PETROCHEMICALS INC. (CORUNNA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	 Maximum	 Average	Unit(3)
Aluminum	12	100	180.000	500.000	312.500	µg/l
COD	12	100	30.000	99.000	60.917	mg/l
Cyanide Total	12	100	.003	.014	.007	mg/l
DOC	152	100	3.000	79.000	17.139	mg/l
Hydrogen ion (pH)	357	100	6.570	8.800	7.829	
Nitrate+Nitrite	12	100	1.000	2.700	2.183	mg/l
Specific conductance	12	100	2,280.000	2,830.000	2,519.000	µS/cm
TOC	149	100	6.000	83.000	21.107	mg/l
Total Kjeldahl nitrogen	12	100	1.700	3.600	2.250	mg/l
Total phosphorus	153	100	.040	1.260	.292	mg/l
Total suspended solids	157	100	6.000	41.000	16.854	mg/l
Zinc	144	100	10.000	1,010.000	438.611	µg/l
VSS	354	98	3.000	25.000	9.151	mg/l
Sulphide	153	97	.019	.650	.227	mg/l
Ammonia plus Ammonium	153	95	.080	9.800	.738	mg/l
Chromium	139	94	6.600	550.000	246.209	µg/l
Phenolics (4AAP)	351	93	2.000	33.000	5.835	µg/l
Chloroform	12	83	.370	1.300	.753	µg/l
Arsenic	12	50	3.000	38.000	11.000	µg/l
Oil and grease	153	49	1.000	15.000	2.269	mg/l
Bis(2-ethylhexyl) phthalate	12	42	1.400	2.400	1.533	µg/l
Copper	12	33	3.000	30.000	8.083	µg/l
Di-n-butyl phthalate	12	33	1.100	1.200	1.108	µg/l
Methylene chloride	12	25	.300	3.200	.842	µg/l
Vanadium	12	25	3.000	3.000	3.000	µg/l
Benz(a)anthracene	12	17	.200	.290	.210	µg/l
Benzylbutylphthalate	12	17	.600	12.000	1.642	µg/l
Chrysene	12	17	.300	.430	.317	µg/l
4-Nitrophenol	12	8	1.400	1.600	1.417	µg/l
Benzo(b)fluoranthene	12	8	.400	.400	.400	µg/l
Indeno(1,2,3-cd)pyrene	12	8	.600	.860	.622	µg/l
Mercury	12	8	.019	.130	.028	µg/l
Nickel	12	8	16.000	29.000	17.083	µg/l
Benzene	153	1	.220	.800	.247	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A1.5
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT SHELL CANADA PRODUCTS LIMITED (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Aluminum	12	100	220.000	2,700.000	1,175.833	µg/l
COD	12	100	13.000	110.000	49.833	mg/l
Cyanide Total	12	100	.004	.016	.009	mg/l
DOC	160	100	3.000	256.000	18.806	mg/l
Hydrogen ion (pH)	363	100	6.400	8.800	7.705	
Specific conductance	12	100	442.000	1,100.000	679.167	µS/cm
TOC	161	100	4.000	308.000	27.088	mg/l
Total Kjeldahl nitrogen	12	100	.260	4.900	1.776	mg/l
Phenolics (4AAP)	361	98	2.000	70.000	6.495	µg/l
Total suspended solids	361	97	4.000	1,038.000	64.767	mg/l
Oil and grease	261	92	.980	15.000	3.452	mg/l
VSS	361	91	2.000	666.000	38.729	mg/l
Zinc	160	84	5.500	800.000	34.516	µg/l
Total phosphorus	161	80	.010	3.230	.496	mg/l
Cobalt	12	75	3.000	21.000	6.750	µg/l
Copper	12	75	3.000	11.000	4.917	µg/l
Nitrate+Nitrite	9	67	.025	.350	.123	mg/l
Vanadium	12	67	3.000	28.000	8.000	µg/l
Arsenic	12	50	3.000	13.000	4.583	µg/l
Chromium	160	43	7.000	150.000	29.314	µg/l
Toluene	159	23	.390	24.798	1.155	µg/l
Ammonia plus Ammonium	261	21	.040	16.900	.469	mg/l
1,2-Dichloropropane	12	17	.500	27.000	2.992	µg/l
m-Xylene and p-Xylene	159	15	.480	42.860	1.273	µg/l
Benzene	160	13	.240	82.223	1.429	µg/l
Antimony	12	8	3.000	14.000	3.917	µg/l
Benzo(b)fluoranthene	12	8	.400	2.600	.583	µg/l
Benzylbutylphthalate	12	8	.600	1.100	.642	µg/l
Bis(2-ethylhexyl) phthalate	12	8	1.400	1.600	1.417	µg/l
Nickel	12	8	10.000	16.000	15.500	µg/l
Phenanthrene	12	8	.300	.350	.304	µg/l
Phenol	12	8	1.100	1.900	1.167	µg/l
Ethylbenzene	160	7	.350	8.970	.462	µg/l
Sulphide	228	6	.020	.600	.024	mg/l
o-Xylene	160	6	.350	16.800	.584	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A1.6
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT SUNCOR INC. (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit(3)
Arsenic	12	100	3.000	8.000	4.583	µg/l
COD	12	100	8.000	27.000	20.667	mg/l
Hydrogen ion (pH)	357	100	6.200	8.400	7.309	
Nitrate+Nitrite	9	100	2.030	13.900	8.162	mg/l
Selenium	12	100	2.000	6.000	3.250	µg/l
Specific conductance	12	100	444.000	1,440.000	1,289.667	µS/cm
Total suspended solids	304	100	2.000	130.000	7.316	mg/l
Zinc	12	100	20.000	110.000	51.667	µg/l
DOC	154	99	.300	91.000	9.143	mg/l
TOC	156	99	.700	88.000	10.186	mg/l
VSS	355	99	1.000	20.000	4.617	mg/l
Ammonia plus Ammonium	162	98	.100	20.000	2.018	mg/l
Total phosphorus	151	98	.040	1.500	.204	mg/l
Phenolics (4AAP)	357	97	1.000	120.000	6.902	µg/l
Oil and grease	154	94	.100	8.900	1.200	mg/l
Total Kjeldahl nitrogen	9	89	.100	.600	.410	mg/l
Aluminum	12	75	30.000	720.000	179.167	µg/l
Sulphide	152	73	.010	.080	.019	mg/l
Cyanide Total	12	67	.005	.060	.018	mg/l
Chloroform	12	50	.200	3.900	.767	µg/l
Total H7CDD	2	50	.040	.060	.050	ng/l
Copper	12	42	10.000	140.000	20.833	µg/l
1,2-Dichloroethane	12	17	.200	.300	.208	µg/l
Nickel	12	17	10.000	10.000	10.000	µg/l
Toluene	159	17	.200	15.200	.513	µg/l
Chrysene	12	8	.300	.400	.308	µg/l
Methylene chloride	12	8	.500	5.400	.908	µg/l
m-Xylene and p-Xylene	159	6	.200	4.300	.497	µg/l
o-Xylene	159	4	.200	5.900	.480	µg/l
Benzene	159	3	.100	11.300	.495	µg/l
Ethylbenzene	159	3	.180	4.900	.234	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A1.7
PROCESS EFFLUENT STREAM
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (NANTICOKE)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Aluminum	12	100	20.000	240.000	133.333	µg/l
Arsenic	12	100	5.000	17.000	11.250	µg/l
COD	12	100	11.000	57.000	30.583	mg/l
DOC	163	100	2.100	35.000	7.259	mg/l
Hydrogen ion (pH)	364	100	6.500	8.600	7.757	
Nitrate+Nitrite	12	100	.870	4.410	2.206	mg/l
Selenium	12	100	3.000	8.000	5.500	µg/l
Specific conductance	12	100	,620.000	2,300.000	1,916.667	µS/cm
TOC	19	100	4.800	11.300	6.868	mg/l
Total Kjeldahl nitrogen	12	100	.940	1.630	1.223	mg/l
Zinc	12	100	14.000	40.000	27.000	µg/l
Total suspended solids	160	99	2.000	19.000	6.861	mg/l
VSS	360	98	1.000	12.800	4.335	mg/l
Molybdenum	12	92	4.800	40.000	33.733	µg/l
Ammonia plus Ammonium	160	89	.025	8.790	.340	mg/l
Total phosphorus	164	87	.010	1.300	.290	mg/l
Phenolics (4AAP)	363	81	.200	20.000	4.172	µg/l
Oil and grease	163	74	.700	6.500	1.826	mg/l
Sulphide	162	70	.002	.300	.038	mg/l
Chromium (hexavalent)	12	67	3.100	31.000	13.033	µg/l
Cyanide Total	9	67	.003	.023	.012	mg/l
Mercury	12	67	.050	.150	.081	µg/l
Thallium	12	67	11.000	20.000	16.333	µg/l
Cadmium	12	58	.200	.600	.233	µg/l
Methylene chloride	12	58	.330	33.000	5.944	µg/l
Chloroform	12	50	.360	5.600	1.480	µg/l
Chloromethane	12	50	.370	7.420	2.274	µg/l
Copper	12	42	5.000	10.000	6.550	µg/l
Bis(2-ethylhexyl) phthalate	3	33	1.400	11.000	4.600	µg/l
Di-n-butyl phthalate	3	33	1.100	2.200	1.467	µg/l
1,1-Dichloroethane	12	25	.200	.510	.389	µg/l
1,1-Dichloroethylene	12	25	.320	1.560	.567	µg/l
Vanadium	12	25	4.700	9.000	5.433	µg/l
Benzene	160	17	.130	2.100	.255	µg/l
Bromomethane	12	17	.830	2.400	1.634	µg/l
Chromium	12	17	8.740	10.000	8.953	µg/l
Lead	12	17	3.000	4.000	3.083	µg/l
Nickel	12	17	5.550	8.000	5.942	µg/l
Phenol	12	17	.240	1.100	.540	µg/l
Toluene	160	13	.050	1.290	.260	µg/l
o-Xylene	160	12	.050	1.520	.158	µg/l
2-Methylnaphthalene	12	8	.220	1.500	.540	µg/l
Ethylbenzene	160	8	.060	.360	.155	µg/l
m-Xylene and p-Xylene	160	4	.110	1.680	.204	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE A2.0
PROCESS EFFLUENT STREAMS
MONTHLY AVERAGE FLOW (m^3/day) FOR SEVEN REFINERIES

REFINERY	DEC 88	JAN 89	FEB 89	MAR 89	APR 89	MAY 89	JUN 89	JUL 89	AUG 89	SEP 89	OCT 89	NOV 89
ESSO (SARNIA)	26,272	26,270	25,295	22,061	24,282	32,249	31,370	30,761	29,695	33,079	28,556	27,296
PETRO-CANADA (MISS.)	9,166	8,959	8,591	9,602	10,966	8,584	13,388	11,559	12,935	12,019	11,655	13,647
PETRO-CANADA (OAK.)	4,053	4,635	4,663	4,261	4,626	5,193	5,768	5,507	5,328	5,021	4,859	4,858
NOVACOR (CORUNNA)	4,919	5,630	5,363	6,429	6,866	5,206	6,219	6,674	6,073	5,376	5,445	5,825
SHELL (SARNIA)	11,148	10,900	11,516	12,136	12,223	13,568	13,703	15,768	15,828	16,393	13,690	12,634
SUNCOR (SARNIA)	9,300	9,191	8,175	8,519	9,450	8,725	9,364	8,461	9,602	9,483	9,362	8,298
ESSO (NANTICOKE)	5,248	6,203	7,043	6,026	7,942	7,719	6,734	6,347	6,017	6,404	6,345	6,557

TABLE A3.0
PROCESS EFFLUENT STREAMS
AVERAGE DAILY LOADING (kg/day)
FOR DAILY AND THRICE WEEKLY PARAMETERS FOR SEVEN REFINERIES
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

	REFINERY						
PARAMETER	1	2	3	4	5	6	7
Ammonia plus Ammonium	15.297	41.537	21.796	4.262	5.662	17.923	2.174
Benzene	.053	.002	.003	.001	.018	.004	.002
Chromium	.522	1.361	.409	1.457	.384	.150	.059
DOC	268.510	136.826	84.877	100.671	252.788	80.885	46.791
Ethylbenzene	.022	.002	.001	.002	.006	.002	.001
Oil and grease	32.813	48.533	11.703	12.659	43.751	10.790	11.869
Phenolics (4AAP)	.096	.104	.196	.035	.083	.063	.028
Sulphide	1.180	1.302	.817	1.345	.334	.176	.246
TOC	386.673	210.336	129.078	124.922	361.430	90.530	45.913
Toluene	.053	.002	.002	.002	.015	.005	.002
Total phosphorus	27.967	2.362	3.683	1.659	6.520	1.784	1.739
Total suspended solids	358.881	321.211	112.619	102.751	815.127	66.155	45.406
VSS	306.444	176.292	72.966	53.821	492.075	41.699	28.946
Zinc	.468	1.014	5.951	2.559	.444	.397	.177
m-Xylene and p-Xylene	.066	.007	.003	.003	.018	.004	.001
o-Xylene	.045	.008	.013	.003	.008	.004	.001

APPENDIX B

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APPENDIX B

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TABLE B1.0-O
ONCE-THROUGH COOLING WATER EFFLUENT STREAM PRIORITY POLLUTANTS FOUND IN FOUR REFINERIES

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Hydrogen ion (pH)	799	100	6.400	8.800	7.793	
DOC	145	99	.480	32.700	7.654	mg/l
TOC	222	98	.810	42.000	10.152	mg/l
Total suspended solids	462	86	1.000	91.000	10.402	mg/l
Oil and grease	500	78	.200	10.000	2.250	mg/l
Zinc	96	69	7.000	90.000	16.431	µg/l
Phenolics (4AAP)	525	68	1.000	34.000	3.187	µg/l
Toluene	136	62	.100	66.400	3.737	µg/l
VSS	289	61	1.000	54.000	6.055	mg/l
Benzene	144	59	.100	39.230	2.083	µg/l
m-Xylene and p-Xylene	142	58	.110	74.230	2.890	µg/l
o-Xylene	143	50	.100	23.240	1.355	µg/l
Ethylbenzene	143	42	.180	43.390	1.101	µg/l
Total phosphorus	55	31	.010	3.200	.145	mg/l
Ammonia plus Ammonium	418	13	.025	13.000	.266	mg/l
Chromium	96	9	8.000	90.000	18.427	µg/l
Sulphide	383	9	.006	.420	.021	mg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE B1.1-O
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND IN OTCW AT ESSO PETROLEUM CANADA (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
DOC	36	100	1.000	11.000	4.207	mg/l
Hydrogen ion (pH)	36	100	6.800	8.700	8.250	
TOC	36	100	1.000	10.000	4.585	mg/l
Total suspended solids	36	83	1.000	33.400	6.539	mg/l
VSS	36	81	1.000	7.500	3.008	mg/l
Toluene	29	76	.500	13.800	2.579	µg/l
Benzene	35	60	.500	16.600	1.921	µg/l
Ammonia plus Ammonium	33	58	.120	.500	.205	mg/l
m-Xylene and p-Xylene	35	43	.500	7.000	1.457	µg/l
o-Xylene	35	37	.400	3.800	.903	µg/l
Ethylbenzene	35	26	.200	2.900	.600	µg/l
Sulphide	36	11	.020	.420	.031	mg/l
Oil and grease	36	8	1.000	2.500	1.053	mg/l
Phenolics (4AAP)	36	8	1.100	7.000	2.211	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE B1.1-I
INTAKE WATER CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Hydrogen ion (pH)	354	100	7.200	9.100	8.147	
Nitrate+Nitrite	12	100	.230	.380	.294	mg/l
Specific conductance	12	100	207.000	217.000	211.750	µS/cm
TOC	157	99	.500	14.000	4.172	mg/l
Total suspended solids	158	99	1.000	48.400	6.746	mg/l
DOC	157	97	.050	13.000	3.367	mg/l
VSS	352	95	1.000	22.350	3.575	mg/l
COD	12	92	5.000	18.000	8.667	mg/l
Total Kjeldahl nitrogen	12	83	.100	.230	.154	mg/l
Aluminum	12	50	30.000	1,000.000	230.083	µg/l
Zinc	12	50	10.000	17.000	10.833	µg/l
Toluene	150	48	.200	10.600	.898	µg/l
Methylene chloride	12	42	.500	1.100	.633	µg/l
Benzene	150	34	.100	8.200	.687	µg/l
Arsenic	12	25	2.000	2.000	2.000	µg/l
Ammonia plus Ammonium	157	23	.025	1.350	.158	mg/l
m-Xylene and p-Xylene	150	21	.110	167.100	1.671	µg/l
Cyanide Total	12	17	.005	31.000	2.590	mg/l
Lead	12	17	30.000	50.000	31.667	µg/l
Phenolics (4AAP)	354	14	.200	9.000	1.916	µg/l
Total phosphorus	153	14	.010	1.150	.109	mg/l
Oil and grease	157	10	.100	13.000	1.041	mg/l
Chromium	12	8	20.000	35.000	21.250	µg/l
o-Xylene	150	8	.050	63.200	.932	µg/l
Ethylbenzene	150	5	.100	31.200	.710	µg/l
Sulphide	156	4	.002	.040	.018	mg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE B1.2-O
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND IN OTCW AT PETRO-CANADA INC., LAKE ONTARIO REFINERY - MISSISSAUGA PLANT

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
DOC	24	100	2.700	32.700	8.567	mg/l
Hydrogen ion (pH)	24	100	6.700	8.700	7.629	
TOC	24	100	2.700	36.200	9.208	mg/l
Ammonia plus Ammonium	22	91	.040	13.000	1.239	mg/l
Total suspended solids	24	88	1.400	13.500	3.921	mg/l
VSS	24	83	1.000	4.100	1.817	mg/l
Zinc	24	83	7.000	90.000	23.250	µg/l
Sulphide	24	75	.010	.060	.023	mg/l
Toluene	24	71	.100	5.240	.627	µg/l
m-Xylene and p-Xylene	24	71	.110	3.660	.660	µg/l
o-Xylene	24	67	.100	2.730	.457	µg/l
Oil and grease	24	63	.710	4.500	1.304	mg/l
Benzene	24	58	.100	3.400	.342	µg/l
Ethylbenzene	24	46	.200	.790	.297	µg/l
Chromium	24	17	8.000	90.000	11.875	µg/l
Phenolics (4AAP)	24	8	2.000	34.000	3.413	µg/l

TABLE B1.2-I
INTAKE WATER CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT PETRO-CANADA INC., LAKE ONTARIO REFINERY - MISSISSAUGA PLANT

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Ammonia plus Ammonium	17	100	.050	36.000	2.203	mg/l
DOC	20	100	1.900	20.900	5.063	mg/l
Hydrogen ion (pH)	21	100	6.500	8.200	7.552	
Nitrate+Nitrite	11	100	.164	.470	.316	mg/l
Specific conductance	11	100	311.000	371.000	328.455	µS/cm
TOC	20	100	2.500	25.700	7.172	mg/l
Total suspended solids	21	100	1.500	11.700	4.533	mg/l
Total Kjeldahl nitrogen	11	91	.100	.330	.235	mg/l
Molybdenum	10	90	4.000	90.000	30.900	µg/l
VSS	21	90	1.000	3.600	1.786	mg/l
Aluminum	10	80	6.000	140.000	62.500	µg/l
Nickel	10	70	2.000	12.000	3.660	µg/l
Zinc	22	64	2.000	116.000	27.136	µg/l
Oil and grease	21	62	.710	2.200	1.047	mg/l
COD	11	45	8.000	30.000	13.636	mg/l
Vanadium	10	40	5.000	9.000	6.000	µg/l
Chromium	22	36	2.000	70.000	11.273	µg/l
Sulphide	21	33	.010	.040	.016	mg/l
Arsenic	10	30	.500	1.100	.700	µg/l
Cobalt	10	30	3.000	10.000	4.500	µg/l
Selenium	10	30	.600	1.400	1.170	µg/l
Thallium	10	30	30.000	260.000	96.000	µg/l
Phenolics (4AAP)	21	24	2.000	5.800	2.267	µg/l
Total phosphorus	11	18	.062	.120	.067	mg/l
m-Xylene and p-Xylene	21	14	.110	.400	.164	µg/l
Antimony	10	10	.500	.500	.500	µg/l
Benzene	21	10	.100	.300	.132	µg/l
Copper	10	10	8.000	10.000	8.200	µg/l
Silver	10	10	3.000	3.000	3.000	µg/l
Toluene	21	10	.100	.300	.139	µg/l
Styrene	12	8	.200	3.020	.468	µg/l
o-Xylene	21	5	.100	.500	.160	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE B1.3-O
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND IN OTCW AT SHELL CANADA PRODUCTS LIMITED (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Hydrogen ion (pH)	722	100	6.700	8.800	7.774	
DOC	72	99	.480	31.000	10.021	mg/l
TOC	146	97	3.000	42.000	12.521	mg/l
Oil and grease	423	85	.980	10.000	2.475	mg/l
Total suspended solids	385	85	3.000	91.000	11.462	mg/l
Phenolics (4AAP)	448	77	1.000	17.500	3.256	µg/l
m-Xylene and p-Xylene	71	66	.460	74.230	4.577	µg/l
Zinc	72	64	10.000	60.000	14.158	µg/l
Toluene	71	58	.500	66.400	5.700	µg/l
Benzene	73	56	.500	39.230	2.824	µg/l
o-Xylene	72	54	.350	23.240	1.975	µg/l
VSS	212	52	1.000	54.000	7.344	mg/l
Ethylbenzene	72	51	.350	43.390	1.735	µg/l
Total phosphorus	55	31	.010	3.200	.145	mg/l
Chromium	72	7	20.000	54.000	20.611	µg/l
Ammonia plus Ammonium	363	4	.025	2.960	.212	mg/l
Sulphide	309	1	.020	.090	.020	mg/l

TABLE B1.3-I
INTAKE WATER CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT SHELL CANADA PRODUCTS LIMITED (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Aluminum	12	100	27.000	170.000	90.667	µg/l
Hydrogen ion (pH)	365	100	6.500	8.700	7.628	
Specific conductance	12	100	207.000	738.000	279.583	µS/cm
DOC	21	95	.480	30.000	9.128	mg/l
TOC	65	92	3.000	47.000	10.374	mg/l
Nitrate+Nitrite	9	89	.270	.320	.298	mg/l
Total suspended solids	171	80	2.000	108.000	11.813	mg/l
Oil and grease	171	79	.980	11.000	2.502	mg/l
COD	12	58	6.216	35.000	10.790	mg/l
Copper	12	58	3.000	22.000	4.917	µg/l
Total Kjeldahl nitrogen	12	50	.227	.830	.369	mg/l
Phenolics (4AAP)	171	48	1.000	9.000	2.451	µg/l
Cobalt	12	42	3.000	12.000	4.833	µg/l
VSS	73	36	1.000	107.000	7.068	mg/l
Zinc	21	33	1.000	40.000	8.214	µg/l
Chloromethane	12	25	2.300	8.100	3.467	µg/l
Cyanide Total	12	25	.002	.004	.002	mg/l
Antimony	12	17	3.000	11.000	4.000	µg/l
Total phosphorus	20	15	.010	.360	.061	mg/l
Benzene	21	14	.240	1.837	.467	µg/l
Chromium	21	10	2.000	20.000	11.095	µg/l
m-Xylene and p-Xylene	21	10	.480	.940	.570	µg/l
Arsenic	12	8	3.000	8.000	3.417	µg/l
Di-n-butyl phthalate	12	8	1.100	6.300	1.533	µg/l
Nickel	12	8	14.000	16.000	15.833	µg/l
Ammonia plus Ammonium	171	5	.050	.390	.197	mg/l
Toluene	21	5	.390	.580	.449	µg/l
Sulphide	149	2	.020	.040	.020	mg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE B1.4-O
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND IN OTCW AT SUNCOR INC. (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
DOC	13	100	1.400	3.800	2.408	mg/l
Hydrogen ion (pH)	17	100	6.400	8.300	7.859	
TOC	16	100	.810	4.100	2.482	mg/l
Total suspended solids	17	100	1.000	10.000	3.706	mg/l
VSS	17	94	1.000	10.000	2.412	mg/l
Benzene	12	75	.440	6.500	1.527	µg/l
Oil and grease	17	59	.200	1.100	.535	mg/l
Phenolics (4AAP)	17	59	1.000	28.000	3.118	µg/l
Sulphide	14	57	.006	.030	.013	mg/l
Toluene	12	33	.210	7.000	1.137	µg/l
m-Xylene and p-Xylene	12	33	.450	10.100	1.550	µg/l
Ethylbenzene	12	25	.180	1.300	.362	µg/l
o-Xylene	12	25	.340	4.300	.751	µg/l

TABLE B1.4-I
INTAKE WATER
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT SUNCOR INC. (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
COD	12	100	7.000	20.000	10.000	mg/l
Hydrogen ion (pH)	158	100	6.300	8.600	7.720	
Nitrate+Nitrite	6	100	.140	.310	.232	mg/l
Specific conductance	12	100	328.000	1,330.000	492.167	µS/cm
Total Kjeldahl nitrogen	6	100	.140	.450	.250	mg/l
Total suspended solids	147	100	1.000	52.000	5.660	mg/l
DOC	148	99	.300	20.000	2.522	mg/l
TOC	148	99	.700	39.000	2.940	mg/l
VSS	144	93	1.000	10.000	2.514	mg/l
Total phosphorus	147	81	.030	.960	.124	mg/l
Phenolics (4AAP)	147	63	.200	15.000	3.185	µg/l
Ammonia plus Ammonium	145	59	.100	1.900	.324	mg/l
Oil and grease	149	57	.100	10.000	.815	mg/l
1,2-Dichloroethane	12	50	.200	.400	.233	µg/l
Chloromethane	12	42	2.000	5.200	2.583	µg/l
Sulphide	147	42	.010	.050	.013	mg/l
Benzene	157	39	.100	16.600	1.187	µg/l
Toluene	157	32	.200	8.700	.520	µg/l
Ethylbenzene	157	18	.180	4.600	.279	µg/l
Aluminum	12	17	30.000	50.000	32.500	µg/l
Cyanide Total	12	17	.005	.100	.013	mg/l
Methylene chloride	12	17	.500	1.700	.700	µg/l
1,2-Dichloropropane	12	8	.200	.200	.200	µg/l
Copper	12	8	10.000	60.000	14.167	µg/l
Pyrene	12	8	.500	.500	.500	µg/l
m-Xylene and p-Xylene	156	5	.200	3.000	.482	µg/l
o-Xylene	157	4	.200	4.600	.382	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE B2.0-O
ONCE-THROUGH COOLING WATER EFFLUENT STREAM MONTHLY AVERAGE FLOW (m^3/day) FOR THE FOUR REFINERIES

MONTH	Esso Sarnia	Petro-Canada Mississauga	Shell Canada Sarnia	Suncor Inc. Sarnia
DEC 88	181,734	95,030	156,090	83,290
JAN 89	162,226	115,537	148,882	82,822
FEB 89	197,193	100,115	149,678	74,680
MAR 89	89,800	89,850	140,042	73,513
APR 89	185,380	108,586	114,158	69,280
MAY 89	237,604	107,146	139,669	91,340
JUN 89	234,770	120,045	166,088	96,145
JUL 89	177,850	140,742	189,462	103,280
AUG 89	186,894	140,465	204,697	106,833
SEP 89	139,874	149,109	200,145	87,560
OCT 89	(1)	144,830	172,125	81,160
NOV 89	184,093	147,562	131,570	72,950

TABLE B3.0-O
ONCE-THROUGH COOLING WATER EFFLUENT STREAM AVERAGE DAILY LOADING (kg/day) FOR PRIORITY POLLUTANTS DETECTED AT FOUR REFINERIES
(DECEMBER 1, 1989 - NOVEMBER 30, 1990)

PARAMETER	Esso Sarnia	Petro-Canada Mississauga	Shell Canada Sarnia	Suncor Inc. Sarnia
Ammonia plus Ammonium	41.06	147.06	34.07	.
Benzene	.38	.03	.38	.12
Chromium	.	1.09	3.12	.
DOC	886.48	1,058.23	1,573.66	200.27
Ethylbenzene	.12	.04	.23	.02
Oil and grease	207.28	124.50	386.30	42.44
Phenolics (4AAP)	.40	.61	.54	.25
Sulphide	5.72	2.36	3.22	.89
TOC	952.56	1,115.77	2,063.81	204.37
Toluene	.47	.08	.77	.08
Total phosphorus	.	.	23.17	.
Total suspended solids	1,009.32	365.87	1,904.32	303.37
VSS	450.51	179.06	1,158.38	195.06
Zinc	.	2.40	2.15	.
m-Xylene and p-Xylene	.27	.08	.63	.13
o-Xylene	.17	.06	.27	.07

NOTE (1) - Although sample records exist for the parameter, there are no corresponding discharge data.

APPENDIX C

SUMMARY TABLES FOR LANDFARM LEACHATE DATA

APPENDIX C

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TABLE C1.0
LANDFARM LEACHATE CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT TWO REFINERIES

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Aluminum	3	100	40.000	450.000	240.000	µg/l
COD	3	100	61.000	81.000	68.333	mg/l
Chromium (hexavalent)	2	100	6.500	6.550	6.525	µg/l
Cyanide Total	3	100	.003	.042	.017	mg/l
DOC	25	100	11.500	86.000	35.150	mg/l
Hydrogen ion (pH)	27	100	6.800	8.500	7.346	
Molybdenum	3	100	9.000	140.000	76.333	µg/l
Nitrate+Nitrite	3	100	2.490	44.100	20.863	mg/l
Specific conductance	3	100	1,420.000	1,725.000	1,623.333	µS/cm
TOC	13	100	19.750	91.000	41.173	mg/l
Total Kjeldahl nitrogen	3	100	1.500	2.300	1.938	mg/l
Total suspended solids	27	100	3.000	134.400	20.414	mg/l
Zinc	5	100	2.000	100.000	49.400	µg/l
Phenolics (4AAP)	26	92	2.000	14.000	5.231	µg/l
VSS	27	89	1.300	18.250	5.016	mg/l
Ammonia plus Ammonium	26	85	.025	1.755	.362	mg/l
Sulphide	27	81	.002	.190	.047	mg/l
Oil and grease	27	70	1.000	8.000	3.042	mg/l
Cadmium	3	67	.200	2.000	.800	µg/l
Copper	3	67	3.000	7.500	5.167	µg/l
Vanadium	3	67	7.500	20.000	12.833	µg/l
1,2,4-Trichlorobenzene	2	50	.002	.044	.023	µg/l
2,4,5-Trichlorotoluene	2	50	.002	.005	.004	µg/l
Hexachlorobutadiene	2	50	.003	.007	.005	µg/l
Methylene chloride	2	50	.300	6.350	3.325	µg/l
Pentachlorobenzene	2	50	.003	.023	.013	µg/l
Total phosphorus	27	37	.013	.900	.167	mg/l
4-Nitrophenol	3	33	.375	19.750	7.175	µg/l
5-nitro, Acenaphthene	3	33	.800	1.800	1.300	µg/l
Acrolein	3	33	3.000	5.550	3.850	µg/l
Benzylbutylphthalate	3	33	.600	2.900	1.667	µg/l
Cobalt	3	33	3.000	20.000	10.667	µg/l
Lead	3	33	3.000	21.000	9.833	µg/l
Mercury	3	33	.019	.057	.043	µg/l
Nickel	3	33	13.000	16.000	14.667	µg/l
Selenium	3	33	.960	3.000	1.653	µg/l
Thallium	3	33	11.000	80.000	37.667	µg/l
Benzene	25	28	.130	.375	.228	µg/l
Toluene	25	24	.050	.880	.316	µg/l
Chromium	5	20	2.000	20.000	15.300	µg/l
Ethylbenzene	25	20	.060	.360	.224	µg/l
o-Xylene	25	20	.050	.420	.242	µg/l
m-Xylene and p-Xylene	25	12	.110	.480	.290	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE C1.1
LANDFARM LEACHATE
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT NOVACOR PETROCHEMICALS INC. (CORUNNA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2)			Unit (3)
			Minimum	Maximum	Average	
Aluminum	1	100	40.000	40.000	40.000	µg/l
Benzylbutylphthalate	1	100	1.500	1.500	1.500	µg/l
COD	1	100	61.000	61.000	61.000	mg/l
Cyanide Total	1	100	.003	.003	.003	mg/l
DOC	7	100	12.000	48.000	35.857	mg/l
Hydrogen ion (pH)	7	100	7.150	8.500	7.850	
Molybdenum	1	100	9.000	9.000	9.000	µg/l
Nitrate+Nitrite	1	100	16.000	16.000	16.000	mg/l
Phenolics (4AAP)	6	100	2.000	14.000	5.833	µg/l
Specific conductance	1	100	1,420.000	1,420.000	1,420.000	µS/cm
TOC	6	100	26.000	59.000	44.833	mg/l
Total Kjeldahl nitrogen	1	100	1.500	1.500	1.500	mg/l
Total suspended solids	7	100	3.000	17.000	7.571	mg/l
Vanadium	1	100	11.000	11.000	11.000	µg/l
Zinc	3	100	2.000	40.000	24.000	µg/l
Sulphide	7	71	.020	.110	.047	mg/l
Ammonia plus Ammonium	7	57	.160	1.200	.424	mg/l
VSS	7	57	3.000	10.000	4.869	mg/l
Oil and grease	7	29	1.000	8.000	2.671	mg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE C1.2
LANDFARM LEACHATE
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (NANTICOKE)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Aluminum	2	100	230.000	450.000	340.000	µg/l
COD	2	100	63.000	81.000	72.000	mg/l
Cadmium	2	100	.200	.200	.200	µg/l
Chromium (hexavalent)	2	100	6.500	6.550	6.525	µg/l
Copper	2	100	5.000	7.500	6.250	µg/l
Cyanide Total	2	100	.005	.042	.023	mg/l
DOC	18	100	11.500	86.000	34.875	mg/l
Hydrogen ion (pH)	20	100	6.800	7.900	7.170	
Methylene chloride	1	100	6.350	6.350	6.350	µg/l
Molybdenum	2	100	80.000	140.000	110.000	µg/l
Nitrate+Nitrite	2	100	2.490	44.100	23.295	mg/l
Specific conductance	2	100	1,725.000	1,725.000	1,725.000	µS/cm
TOC	7	100	19.750	91.000	38.036	mg/l
Total Kjeldahl nitrogen	2	100	2.015	2.300	2.157	mg/l
Total suspended solids	20	100	4.400	134.400	24.908	mg/l
VSS	20	100	1.300	18.250	5.067	mg/l
Zinc	2	100	75.000	100.000	87.500	µg/l
Ammonia plus Ammonium	19	95	.025	1.755	.339	mg/l
Phenolics (4AAP)	20	90	2.000	13.500	5.050	µg/l
Oil and grease	20	85	1.037	7.700	3.172	mg/l
Sulphide	20	85	.002	.190	.047	mg/l
1,2,4-Trichlorobenzene	2	50	.002	.044	.023	µg/l
2,4,5-Trichlorotoluene	2	50	.002	.005	.004	µg/l
4-Nitrophenol	2	50	.375	19.750	10.063	µg/l
5-nitro, Acenaphthene	2	50	.800	1.300	1.050	µg/l
Acrolein	2	50	3.000	5.550	4.275	µg/l
Chromium	2	50	14.500	20.000	17.250	µg/l
Cobalt	2	50	9.000	20.000	14.500	µg/l
Hexachlorobutadiene	2	50	.003	.007	.005	µg/l
Lead	2	50	3.000	5.500	4.250	µg/l
Mercury	2	50	.053	.057	.055	µg/l
Nickel	2	50	13.000	15.000	14.000	µg/l
Pentachlorobenzene	2	50	.003	.023	.013	µg/l
Selenium	2	50	.960	1.000	.980	µg/l
Thallium	2	50	11.000	80.000	45.500	µg/l
Total phosphorus	20	50	.070	.900	.213	mg/l
Vanadium	2	50	7.500	20.000	13.750	µg/l
Benzene	18	39	.130	.375	.224	µg/l
Toluene	18	33	.050	.880	.287	µg/l
Ethylbenzene	18	28	.060	.360	.171	µg/l
o-Xylene	18	28	.050	.420	.173	µg/l
m-Xylene and p-Xylene	18	17	.110	.480	.217	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE C2.1
LANDFARM LEACHATE MONTHLY FLOW RESULTS FOR NOVACOR PETROCHEMICALS INC. (CORUNNA)
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

MONTH	TOTAL VOLUME DISCHARGED (cu. meters)	TOTAL DISCHARGE DURATION (hours)
FEB 89	568.0	5.0
MAR 89	1,661.0	16.0
APR 89	1,310.0	10.0
MAY 89	541.0	5.0

TABLE C2.2
LANDFARM LEACHATE MONTHLY FLOW RESULTS FOR ESSO PETROLEUM CANADA (NANTICOKE)
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

MONTH	TOTAL VOLUME DISCHARGED (cu. meters)	TOTAL DISCHARGE DURATION (hours)
DEC 88	5.8	.2
JAN 89	59.3	76.0
APR 89	1,156.0	30.0
SEP 89	3,698.0	94.8
OCT 89	1,675.0	48.5
NOV 89	4,566.0	148.5

TABLE C3.0
LANDFARM LEACHATE
TOTAL MASS LOADING (kg) FOR PARAMETERS CALCULATED AT TWO REFINERIES
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

PARAMETER	Novacor Corunna	Esso Nanticoke
2,4-Dinitrophenol	(1)	.04
4,6-Dinitro-o-cresol	(1)	.01
4-Nitrophenol	(1)	.02
Aluminum	(1)	.52
Ammonia plus Ammonium	1.29	2.11
Antimony	(1)	.01
Beryllium	(1)	.01
Bis(2-ethylhexyl) phthalate	(1)	.01
COD	(1)	72.83
Chromium	.04	.02
Chromium (hexavalent)	(1)	.01
Cobalt	(1)	.02
Copper	(1)	.01
Cyanide Total	(1)	.05
DOC	146.43	610.80
Molybdenum	(1)	.16
Nickel	(1)	.02
Nitrate+Nitrite	(1)	50.98
Octachlorodibenzo-p-dioxin	(1)	.10
Octachlorodibenzofuran	(1)	.09
Oil and grease	8.66	42.51
PCBT	(1)	57.80
Phenolics (4AAP)	.03	.09
Silver	(1)	.01
Sulphide	.20	.60
TOC	180.90	280.73
Thallium	(1)	.09
Total H6CDD	(1)	.07
Total H6CDF	(1)	.06
Total H7CDD	(1)	.07
Total H7CDF	(1)	.06
Total Kjeldahl nitrogen	(1)	2.66
Total PCDD	(1)	.02
Total PCDF	(1)	.02
Total TCDD	(1)	.03
Total TCDF	(1)	.05
Total phosphorus	.16	2.54
Total suspended solids	34.06	347.13
VSS	21.43	83.98
Vanadium	(1)	.02
Zinc	.06	.09

NOTE (1) - Corresponding discharge data not available.

APPENDIX D

SUMMARY TABLES FOR STORM WATER DATA

APPENDIX D

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Table D1.3 Storm water Effluent Streams Conventional and Priority Pollutants Found At Esso Petroleum Canada (Nanticoke) D-2

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Table D2.2 Storm water Effluent Streams Monthly Flow Results For Shell Canada Products Limited (Sarnia) D-3

Table D2.3 Storm water Effluent Streams Monthly Flow Results For Esso Petroleum Canada (Nanticoke) D-4

Table D3.0 Storm water Effluent Streams Total Mass Loading (kg) For Parameters Calculated At Three Refineries D-4

APPENDIX D

TABLE D1.0
STORM WATER EFFLUENT STREAMS CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT THREE REFINERIES

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
DOC	153	100	1.600	51.000	8.345	mg/l
Hydrogen ion (pH)	184	100	6.900	9.300	7.852	
TOC	109	100	1.600	61.000	12.557	mg/l
Total suspended solids	184	99	2.800	333.000	43.611	mg/l
Zinc	53	96	7.000	2,626.000	242.755	µg/l
VSS	184	84	1.000	64.000	6.729	mg/l
Total phosphorus	163	67	.010	6.310	.235	mg/l
Phenolics (4AAP)	185	65	1.100	25.000	4.136	µg/l
Ammonia plus Ammonium	183	64	.025	7.800	.324	mg/l
Oil and grease	184	64	.800	8.300	2.108	mg/l
Sulphide	157	60	.002	.710	.056	mg/l
o-Xylene	149	20	.050	131.845	1.622	µg/l
Toluene	148	18	.150	29.141	.897	µg/l
Benzene	148	16	.130	64.990	.897	µg/l
Chromium	56	16	11.000	540.000	40.304	µg/l
m-Xylene and p-Xylene	148	15	.110	43.895	1.380	µg/l
Ethylbenzene	150	9	.060	13.810	.443	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE D1.1
STORM WATER EFFLUENT STREAMS CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT NOVACOR PETROCHEMICALS INC. (CORUNNA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
DOC	24	100	4.000	17.000	9.292	mg/l
Hydrogen ion (pH)	26	100	7.700	8.500	8.065	
TOC	24	100	5.000	24.000	11.917	mg/l
Total suspended solids	26	100	8.000	333.000	56.885	mg/l
Zinc	2	100	170.000	220.000	195.000	µg/l
VSS	26	96	2.000	64.000	8.754	mg/l
Sulphide	27	93	.020	.710	.122	mg/l
Phenolics (4AAP)	26	65	2.000	25.000	5.615	µg/l
Total phosphorus	26	65	.040	.360	.080	mg/l
Ammonia plus Ammonium	25	64	.080	.240	.141	mg/l
Oil and grease	26	27	1.000	7.000	1.769	mg/l
Chromium	5	20	20.000	80.000	32.000	µg/l
m-Xylene and p-Xylene	27	4	.480	1.240	.530	µg/l
o-Xylene	27	4	.420	3.680	.541	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE D1.2
STORM WATER EFFLUENT STREAMS
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT SHELL CANADA PRODUCTS LIMITED (SARNIA)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	 Maximum	 Average	Unit (3)
DOC	51	100	3.000	51.000	14.108	mg/l
Hydrogen ion (pH)	73	100	6.900	9.300	7.722	
TOC	51	100	5.000	61.000	18.833	mg/l
Total suspended solids	73	97	4.000	331.000	35.459	mg/l
Zinc	51	96	7.000	2,626.000	244.627	µg/l
Phenolics (4AAP)	74	82	1.100	18.000	5.083	µg/l
Oil and grease	73	81	.980	8.000	2.429	mg/l
Total phosphorus	52	65	.010	6.310	.362	mg/l
VSS	73	64	3.000	26.333	8.831	mg/l
Ammonia plus Ammonium	73	47	.100	7.800	.646	mg/l
Toluene	48	35	.500	29.141	2.173	µg/l
m-Xylene and p-Xylene	48	31	.620	43.895	3.659	µg/l
o-Xylene	49	27	.350	131.845	4.399	µg/l
Benzene	48	21	.500	64.990	2.267	µg/l
Chromium	51	16	11.000	540.000	41.118	µg/l
Ethylbenzene	50	12	.350	13.810	.894	µg/l
Sulphide	45	4	.020	.040	.020	mg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE D1.3
STORM WATER EFFLUENT STREAMS
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (NANTICOKE)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	 Maximum	 Average	Unit (3)
DOC	78	100	1.600	40.000	4.287	mg/l
Hydrogen ion (pH)	85	100	6.900	8.900	7.899	
TOC	34	100	1.600	26.000	3.594	mg/l
Total suspended solids	85	100	2.800	308.000	46.553	mg/l
VSS	85	96	1.000	14.000	4.305	mg/l
Ammonia plus Ammonium	85	79	.025	.840	.101	mg/l
Sulphide	85	79	.002	.520	.053	mg/l
Total phosphorus	85	69	.010	.800	.205	mg/l
Oil and grease	85	60	.800	8.300	1.937	mg/l
Phenolics (4AAP)	85	51	1.500	10.000	2.859	µg/l
o-Xylene	73	22	.050	.550	.158	µg/l
Benzene	73	18	.130	1.870	.239	µg/l
Toluene	73	12	.150	.940	.245	µg/l
Ethylbenzene	73	10	.060	.360	.163	µg/l
m-Xylene and p-Xylene	73	8	.110	.480	.197	µg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement

TABLE D2.1
STORM WATER EFFLUENT STREAMS MONTHLY FLOW RESULTS FOR NOVACOR PETROCHEMICALS INC. (CORUNNA)
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

MONTH	TOTAL VOLUME DISCHARGED (cu. meters)	TOTAL DISCHARGE DURATION (hours)
JAN 89	45,198.0	152.0
FEB 89	6,019.0	21.0
MAR 89	125,449.0	149.0
APR 89	36,119.0	109.0
MAY 89	63,483.0	78.0
JUN 89	56,215.0	87.0
JUL 89	42,132.0	11.0
AUG 89	2,990.0	3.0
SEP 89	17,338.0	84.0
OCT 89	23,697.0	26.0
NOV 89	56,403.0	80.0

TABLE D2.2
STORM WATER EFFLUENT STREAMS MONTHLY FLOW RESULTS FOR SHELL CANADA PRODUCTS LIMITED (SARNIA)
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

MONTH	TOTAL VOLUME DISCHARGED (cu. meters)	TOTAL DISCHARGE DURATION (hours)
DEC 88	52,826.0	115.0
JAN 89	10,936.0	29.5
FEB 89	19,177.0	31.0
MAR 89	42,034.0	68.0
APR 89	1,165.0	4.67
MAY 89	10,860.5	29.5
JUN 89	46,951.0	76.25
JUL 89	40,436.0	61.65
AUG 89	22,351.0	39.0
SEP 89	50,752.9	108.375
OCT 89	34,815.0	55.7
NOV 89	51,733.0	84.175

TABLE D2.3
STORM WATER EFFLUENT STREAMS MONTHLY FLOW RESULTS FOR ESSO PETROLEUM CANADA (NANTICOKE)
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

MONTH	TOTAL VOLUME DISCHARGED (cu. meters)	TOTAL DISCHARGE DURATION (hours)
DEC 88	19,431.0	60.0
JAN 89	15,500.9	39.0
FEB 89	13,482.0	23.0
MAR 89	36,334.0	49.0
APR 89	102,098.0	59.25
MAY 89	17,466.0	19.5
JUN 89	41,610.0	59.25
JUL 89	12,493.0	14.25
AUG 89	57,911.0	61.25
SEP 89	65,362.0	79.5
OCT 89	19,917.0	29.5
NOV 89	133,584.0	127.0

TABLE D3.0
STORM WATER EFFLUENT STREAMS TOTAL MASS LOADING (kg) FOR PARAMETERS CALCULATED AT THREE REFINERIES
(DECEMBER 1, 1988 - NOVEMBER 30, 1989)

PARAMETER	Novacor Corunna	Shell Canada Sarnia	Esso Nanticoke
Ammonia plus Ammonium	65.97	237.83	48.19
Benzene	.12	.42	.14
Chromium	6.04	10.52	(1)
DOC	4,647.21	5,781.38	2,000.56
Ethylbenzene	.18	.61	.09
Oil and grease	905.87	1,163.59	1,065.70
Phenolics (4AAP)	2.57	2.50	1.52
Sulphide	55.88	7.98	34.01
TOC	6,276.91	7,825.79	1,458.48
Toluene	.19	1.00	.12
Total phosphorus	44.72	149.04	117.79
Total suspended solids	25,010.94	15,933.39	28,429.53
VSS	4,130.75	3,733.90	2,458.27
Zinc	24.46	74.09	(1)
m-Xylene and p-Xylene	.27	2.28	.10
o-Xylene	.25	3.66	.08

NOTE (1) - Although sample records exist for the parameter, there are no corresponding discharge data.

APPENDIX E

SUMMARY TABLES FOR EMERGENCY OVERFLOW DATA

APPENDIX E

LIST OF TABLES

Table E1.1 Emergency Overflow Conventional and Priority Pollutants Found At Esso Petroleum Canada (Sarnia) E-1

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TABLE E1.1
EMERGENCY OVERFLOW
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (SARNIA)

Parameter	Concentration (mg/l)	Loading (kg)
Benzene	1.153	0.2
DOC	23.000	4.2
Hydrogen ion (pH)	8.200	-
Oil and grease	38.600	7.0
Phenolics (4AAP)	0.053	0.1
TOC	37.000	6.7
Toluene	3.034	0.5
Total Suspended Solids	212.600	38.9

NOTE: 1) During the year of monitoring, there were two discharges:
January 1989: 159 m^3 in 15 minutes (sample was not taken)
July 1989: 23.8 m^3 discharged in one hour (sample taken)

2) Loading calculation based on total emergency overflow in 1989 of 183 m^3 and the concentrations available for one sample.

TABLE E1.2
EMERGENCY OVERFLOW
CONVENTIONAL AND PRIORITY POLLUTANTS FOUND AT ESSO PETROLEUM CANADA (NANTICOKE)

Parameter	Number of Observations	Frequency of Detection (1)	Concentrations (2) Minimum	Maximum	Average	Unit (3)
Benzene	1	100	1.220	1.220	1.220	µg/l
DOC	1	100	52.000	52.000	52.000	mg/l
Hydrogen ion (pH)	1	100	7.300	7.300	7.300	
Oil and grease	1	100	4.200	4.200	4.200	mg/l
Phenolics (4AAP)	1	100	4.000	4.000	4.000	µg/l
Sulphide	1	100	.030	.030	.030	mg/l
TOC	1	100	58.000	58.000	58.000	mg/l
Total suspended solids	1	100	31.600	31.600	31.600	mg/l
VSS	1	100	8.400	8.400	8.400	mg/l

NOTE: (1) - Frequency of Detection = Frequency of detection above Laboratory Method Detection Limit (%)
(2) - Concentrations from December 1, 1988 to November 30, 1989
(3) - Unit = Unit of Measurement